HYDROLOGIC NETWORK REVIEW

NOVA SCOTIA

JOINTLY PREPARED BY

Environment
Canada

Nova Scotia
Department of
the Environment

Halifax 1985

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ACKNOWLEDGEMENT

This report was prepared, as a joint project by the Nova Scotia Department of the Environment and the Water Resources Branch, Inland Waters Directorate, Environment Canada, as a reference document and planning tool for the Co-ordinating Committee under the Water Quantity Surveys Federal/Provincial Cost Sharing Agreement. Members of this committee are A. J. Crouse, Nova Scotia Department of the Environment and R. D. McBride, Water Resources Branch, Inland Waters Directorate, Environment Canada. Their support of this review project has been greatly appreciated.

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Special thanks are expressed for the drafting support received from R. G. Howatt, Environment Canada and from D. O. Hirtle, Nova Scotia Department of the Environment. The secretarial support from D. B. Birks, Environment Canada; and R. M. Garrison, D. A. Mitchell and H. F. Doubleday has been very commendable.

CHAPTER 1

EXECUTIVE SUMMARY AND RECOMMENDATIONS

1.1 OBJECTIVES AND SCOPE

This review was conducted to determine the adequacy and relevancy of present hydrologic networks and data for current and future needs of Nova Scotia. The overall objective of the networks is to support decision making on the use of water resources for the benefit of all Nova Scotians. This has been a joint project between Nova Scotia Department of the Environment and Water Resources Branch, Inland Waters Directorate, Environment Canada under the Federal/Provincial Water Quantity Cost Sharing Agreement.

The network of monitoring stations has two components. The first and most obvious is the data collection component. The second aspect is the ability of the network to provide data for forecasting purposes and for use in areas where no monitoring is done. The information systems of primary concern in this review are the surface water and groundwater monitoring stations. This report assesses the geographic coverage by relating to established guidelines and standards. The ability to transpose data from one drainage basin to another within the province is assessed by using specific statistical tests.

This report has also focussed on the uses of hydrologic data. A questionnaire was distributed to determine what format and frequency is of most use to those using the current program outputs.

This report has drawn upon previous studies and restates the recommendations not acted upon to date and those recommendations still valid in support of improving the current coverage. A pilot application of new techniques for quantitative evaluation of the error in the instantaneous discharge at selected hydrometric stations has been done to provide guidance to program managers on how resources could be redistributed among stations and how trade-offs between accuracy and cost can be made.

1.2 CONCLUSIONS

1.2.1 General

The results of the users survey showed that the surface water and groundwater data collection networks provide valuable information to many industries, consultants and government agencies. The value of these data is reflected in the 550 million dollar annual value of hydroelectric power generation and the 128 million dollar annual value of a variety of other concerns; a total annual amount of 678 million dollars. The impressive amounts, although from only a sampling of the major users of the data, clearly show the importance of knowledge on the water resources to the economic health of Nova Scotia. The survey also showed that more emphasis must be placed on public relations and marketing in an effort to make more people aware of the availability of this information. It is important to maintain a liaison with the data user community to determine their common needs for data in a more refined format which will make the data readily usable. These efforts will increase the use of the data and improve efficiencies in its usage. The availability of accurate and timely data in support of decisions being made by various designers and managers is a challenge to be continuously addressed by the data collection and interpretation agencies.

1.2.2 Surface Water Network

Statistical analyses were performed on the data to determine trends in runoff, variance and skewness. Correlations between annual and monthly mean discharges were also conducted to determine if acceptable relationships existed between stations. These analyses confirmed the division of the province into the three hydrologic zones as proposed by Ingledow (1970). These zones are: Southwestern Nova Scotia, Cape Breton Highlands, and Northeastern Nova Scotia excluding Cape Breton Highlands. It was determined, as anticipated, that lowflows do not correlate as well as the higher flows and that trends could be seen in the annual runoff over the past 65 years. It was shown that with the exception of two stations little information could be transferred from one station to the next using simple stream to stream correlation techniques. This shows that the hydrologic characteristics are diversified and that little redundancy exists in network coverage. The need for more indepth approaches to develop relationships for transferring data to ungauged sites is indicated.

The lack of coordination between the locations of surface water, groundwater and climatic data collection sites is a major deficiency in the overall hydrologic network in terms of providing a comprehensive data base from which data may be transferred to ungauged sites. It was noted that few groundwater monitoring wells were located in watersheds which contained surface water gauges. It was also noted, that of 53 watersheds gauged by a surface flow station only seven contained a precipitation gauge, one of which was a natural flow station. This lack of coordination restricts the ability to effectively develop a comprehensive water resources management strategy in Nova Scotia.

The usefulness of the shorter term project stations has not been fully capitalized. Twenty-four out of the 53 stations in the surface water network are classified as short term. Little information has been used from these stations in filling voids in the overall network through statistical methods. This valuable source of information essentially in place for other purposes could be utilized to a greater degree.

It was noted that very few river basins had more than one surface flow station even though some basins showed sub-basins with significantly different physiographic characteristics. It was also noted that there is a need for a wider dispersion of gauged basins in all zones and that more information was needed about the smaller coastal watersheds.

An increase, in the mean annual runoff, ranging from 2% to 15%, was noted over the last 15 years in relation to the past 65 years. No single reason was evident for this trend but several were brought forward as avenues to pursue.

Some problems were encountered concerning station designation and information available on regulated streams specifically those where a diversion has effectively changed the contributing area of the watershed.

1.2.3 Groundwater Network

The groundwater network of 30 stations was found to be comprehensive in its limited coverage, and the absence of a groundwater quality monitoring network was very noticeable in the performance of this review. Many large areas which rely heavily on groundwater are lacking information about this resource. Information required to support comprehensive management for present and future needs has yet to be developed. For example, data can be stored on and retrieved using computers, thus making it less costly and time consuming to analyse in a systematic manner. Also analyses performed using available precipitation, temperature and surface water data demonstrate the complex interrelationship of these elements in Nova Scotia.

1.3 RECOMMENDATIONS

1.3.1 General

It is recommended that a concerted effort be made for better coordination of the various networks monitoring the hydrologic cycle, furthering efforts to understand more fully the water resources of Nova Scotia. Serious consideration must be given to include water quality monitoring in current and future hydrologic network planning.

To make the data more usable by the public, a marketing strategy must be developed to make potential users aware of the data as well as to provide feedback on the general and specific requirements of the user community

1.3.2 Surface Water Network

It is recommended that the apportionment of long term stations be divided proportionally among the three hydrologic zones identified. A number of low flow partial record stations should be established in watersheds where groundwater monitoring wells are established.

It is recommended that further studies be undertaken to develop a better understanding of the interrelationships between stations within a hydrologic zone. For example the method of generalized least squares could be applied. The feasibility of relocating gauging station equipment used at stations which correlate closely with other existing stations should be investigated.

In an effort to maximize the benefits from the stream discharge measurement program, it is recommended that uncertainty functions be computed for all active stations having a minimum of 50 streamflow measurements .

A hydrologic data users seminar which would incorporate many of the data suppliers is recommended as a marketing and information gathering forum .

A number of recommendations concerning network expansion from past studies were never enacted. These recommendations, although sometimes site specific, coincide with areas of the province which have been identified as deficient in network coverage. It is recommended that any future expansion of redistribution of the network resources concentrate on the deficient areas. It is also recommended that any reconnaissance be detailed in a report for use by future network reviewers.

It is recommended that diversified watersheds be monitored by more than one station until satisfactory relationships can be established between the stations.

In view of the noted increase in runoff during the past 15 years it is recommended that a study be conducted to determine the causes and persistence of this trend. Possibly this trend has been caused by new methods in data collection, storage or analyses.

It is recommended that the network increase its coverage of small watersheds and in particular those close to the coast, and that sub-networks be created using normal and/or crest gauges where public interest can support on a volunteer basis.

1.3.3 Groundwater Network

It is recommended that the coverage of this network be expanded to encompass the present large void areas along the Eastern Shore, and along the South Shore, Southwestern Nova Scotia and on Cape Breton Island.

It is reccmmended that a groundwater quality monitoring network be established to operate in conjunction with this network.

It is recommended that data collected from these networks be stored in computer compatible formats for more effective retrieval and handling.

Groundwater monitoring sites should be established to monitor hydrostratigraphic units and/or be able to complement surface water monitoring sites.

CHAPTER 2

INTRODUCTION

2.1 PURPOSE OF REVIEW

This review is being conducted to determine the adequacy of present hydrologic networks for the purpose of obtaining data to better manage the water resources of Nova Scotia. For the purpose of this review, network is loosely defined as a group of stations operated to collect a given type of data such as streamflow, meteorologic, or groundwater levels.

Other data such as snow course data and evaporation pan data are not available at enough locations for these to be considered as networks. They will be considered to the extent appropriate in the evaluation of the surface water, groundwater and weather observation stations that exist now.

The principal concern is with surface water flow stations and groundwater level stations and the data being acquired by them. It is obviously not practical to establish and operate one or more stations on every stream or aquifer or even every one that is likely to be drawn upon as a water source or intersected by a roadway. In some cases, streams are similar enough to enable a designer to transfer data from one stream to another. The extent and nature of similarities enabling such data transfer are of critical importance. Similar data transfers may be made with groundwater data, provided the transfer location is in the same aquifer. This review is intended, in part, to identify the important similarities.

If it is possible to determine regions or zones or areas of significant size that are sufficiently homogeneous to enable samples of data to apply to the whole area it would simplify the task of obtaining adequate data for all purposes. By means of various statistical tests, the homogeneity of selected regions will be tested. If satisfactory regional boundaries can be drawn, it will be possible to examine the hydrometric stations in each region or more specifically on the same stream, to determine if they are truly representative and/or if one is redundant, since the data it produces can be produced with sufficient accuracy by some other means.

Conversely if it is not possible to delineate areas that are sufficiently homogeneous for the required purposes, it will be necessary to establish another or other gauging stations to "fill the gaps" so that conceptual modelling and/or statistical analyses may give satisfactorily accurate data for the needs that are identified.

It is difficult to judge the degree of accuracy that is truly required by users of data. A user's survey, done as part of this project, asks for some guidance in this matter but generally designers and users of data wish to have "more accurate" data and are constrained by the cost in money or time of getting greater accuracy. These general constraints apply to the federal and provincial water resources agencies, although perhaps not to some of the surveyed users who do not directly pay for data collection. Through the use of an uncertainty function it is possible to analyze the accuracy of the streamflow record and determine the cost to achieve a specific degree of accuracy. A guide to use in deciding this question might be the effect on design costs wrought by inaccuracies in other projected data entering design considerations, e.g. population growth rates or traffic on a bridge or costs of flood damage.

In addition to stream gauging stations, hydrologic data sources include groundwater observation wells and precipitation gauges. Groundwater observation wells are a relatively recent addition to the hydrologic knowledge of Nova Scotia, dating from the mid 1960's when the province began to study groundwater. The relationship between groundwater and surface water in Nova Scotia so far appears to be only imprecisely defined. This review is intended to refine this understanding or indicate the data needed to do so. Since groundwater data stations are not widespread or numerous such conclusions are uncertain of attainment.

The precipitation data network is long standing. Before any stream gauges were operating in the province some 65 years ago, rain gauges were providing data. The widespread locations of these gauges and their relative abundance, while providing much data, also serve to show the variability of precipitation and the complexity of forecasting or transposing data from one place to another.

In this review the relationships of precipitation to stream flow and groundwater will be discussed along with the possibilities of examining these correlations in the future.

2.2 METHOD OF APPROACH TO REVIEW

A literature search for reports on past studies pertaining to the Nova Scotia hydrologic network, produced three studies. The first, "An Assessment of the Hydrometric Network of the Province of Nova Scotia, Present and Future", was completed by staff of the Water Resources Branch, Energy, Mines and Resources*, in March 1967. The second report, "Hydrometric

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* Water Resources Branch was part of the Department of Energy Mines and Resources in 1967.

Network Plan", completed in December 1970 under contract with T. Ingledow & Associates Ltd., covered the four Atlantic Provinces. The third report, "An Analysis of the Hydrometric Networks of the Atlantic Region", was based on the spatial distribution of the hydrometric stations by drainage area, completed in April 1984 by the Inland Waters Directorate, Water Resources Branch, Hydrology Division, Environment Canada. The conclusions and recommendations of these studies will be outlined and examined to determine what actions were taken as a result of the findings.

A further search for related studies which contained some historic data analyses revealed two studies. The first titled "Analysis of Low Stream Flows on Cape Breton Island, Nova Scotia", was conducted by the Water Planning and Management Branch, Inland Waters Directorate, Environment Canada, Atlantic Region, 1978. The second titled "Regional Flood Frequency Analysis for Mainland Nova Scotia Streams" was conducted by MacLaren Atlantic Ltd., 1980 for the Canada-Nova Scotia Flood Damage Reduction Program. These studies will be reviewed and comparisons made where similar analyses are conducted in this report.

A questionnaire (see Appendix A) was developed to determine what use is being made of data available from the existing networks and by whom. In addition, questions were asked to find where future information is required, what types and in what format. The questionnaire was sent to 150 potential users of these data in Nova Scotia. An approximate annual dollar value for activities related to this kind of information was also requested for the purpose of providing a comparison between this total and the total operating costs of these networks.

2.3 BACKGROUND AND NATURE OF NETWORKS

The water resources of Nova Scotia are widely distributed in a few moderately large lakes and rivers and in a myriad of small streams, ponds, swamps and groundwater aquifers. The numerous small surface sources are significant because many could supply the needs of a small community or industry if adequate storage structures were put in place. However, because of their number it is quite impractical to study and measure each to determine its reliable yield and its flood flow for design of water works.

When water resources first began to be used a watercourse was assessed by the prospective user on an individual subjective basis, i.e. "is the watercourse (today) suitable for the use I have in mind (today)?" This was adequate in the short term for floating a canoe or raft. For longer term uses such as stock watering or energy utilization, more study was required. Thus for a water power plant, observations or measurements over at least a year or preferably more, would necessarily precede a decision to invest capital in a mill or power station.

The information and experience of one designer/operator would doubtless be applied to other sites with the assumption that what applied in a proven site would also apply 100 kilometres away, up or down the coast. Today we still continue this practice of transposing data from one watershed or stream or area to another since we cannot measure all the watercourses.

We know that large watersheds behave differently than small ones on a unit area basis with respect to peak flows, average yields and minimum flows. Just what causes these differences is not always clear although soil and bedrock types, stream slope, proximity to the sea and elevation are probable factors. Precipitation affects the levels of lakes and groundwater, as well as flow rates in streams. A network of precipitation gauges relating to stream flow gauges and groundwater gauge therefore is necessary.

Sediment is always carried by a flowing stream. The quantity depends on factors such as flow velocity and availability of material to erode, which in turn relate to flow rates and soil types in the watershed. These factors are important in streamflow studies. There appears to be value, therefore, in integrating or at least relating studies of sediment to flow studies.

Likewise water quality is affected by some of the same factors as flow and is affected by flow rates. Although a great many factors may affect water quality and many specific determinations of quality indicators have been and will be made, in a general way it is possible and sometimes desirable to relate quality and quantity.

Groundwater is generally interconnected with surface water and, although the relationship may be complex, each affects the other. Therefore, any study of one should take account of the other.

Ideally all the interrelating factors of precipitation, ice and snowmelt or accumulation, groundwater movement, sediment accretion, transport or erosion, impurities in water and flow rates should be measured and studied together. Although the ideal situation is impractical, some degree of integration is certainly feasible.

The existing water quantity measuring stations in Nova Scotia were established generally in response to specifically proposed industrial projects using surface water. Stations were also installed with the intent that they would be representative of an area or region. The latter reason was more applicable to meteorological and sediment stations than streamflow stations, although through the International Hydrological Decade program and various groundwater studies in Nova Scotia, stations for scientific assessment of the resource were established.

Since it is necessary to use existing information and transpose it to ungauged sites, there is a need to 1) assess the accuracy of this practical procedure, and 2) assess the need for additional measuring sites to increase the accuracy of data derived from the network. This study reviews the existing network of streamflow stations and groundwater monitoring stations in the light of current and projected needs and in relation to other networks such as the water quality and meteorologic networks.

2.4 DEVELOPMENT OF STREAM GAUGING AND GROUNDWATER MONITORING NETWORKS

Active field work to measure streamflows in the province on a cooperative basis by Canada and Nova Scotia began in May, 1915. The Water Power Commission of Nova Scotia and the Dominion Water Power Branch made an agreement to undertake the work as a vital first step in determining and using the hydroelectric power potential in the province. Although one of the first authorized users of water under the N.S. Water Act passed in 1919 was Imperial Oil for its refinery needs, hydroelectric power was for many years the main water user.

It is interesting to note that from these earliest days stream flow measurements have been a cooperative effort by Canada and Nova Scotia. It is also noted in the Nova Scotia Annual Report, 1915, Appendix No. 30, that in 1915 the Canadian Meteorological Service (forerunner of Atmospheric Environment Service) was asked to establish additional precipitation stations throughout the province in inland districts to complement the stream gauging stations just then being started.

At its beginning stream gauging was planned on a province wide basis and integrated to some extent with meteorological measurements. A bias toward hydroelectric power development continued until 1955 when the Wreck Cove area began receiving intensive hydrologic study. Pulp mills, being large users of water, caused project specific stream gauging stations to be set up. The Mersey Paper Company and Minas Basin Power and Pulp being based on hydropower, more or less incidentally got the water supply information they needed. Newer mills, e.g. Nova Scotia Forest Industries and Scott Maritimes, required "project" stream stations to determine the water supply potential near the Strait of Canso and on Middle River, Pictou County respectively, as recently as 1965.

Water for human consumption or municipal supply, the most important use was not large enough in flow rates to require detailed hydrometric data. Approximations, with generous factors of "safety" could be used effectively in most instances. Some exceptions, where problems were chronic, eventually were tackled on a better, scientific basis. Gauging stations related to the Antigonish water supply were established, for instance when problems became unmanageable.

Groundwater was largely an unknown quantity, although most people took for granted that a well would produce domestic water supply anywhere it was needed. In 1963 systematic study of groundwater resources began and monitoring of water levels in some areas has been continued.

These networks are perceived by some as a research activity that is a long term investment without short term benefits. As such it suffers from neglect when financial plans are made. However, designers and prospective users of water resources eagerly seek and accept any hydrologic information that is available when they contemplate specific projects. This eagerness has sometimes resulted in project specific network sites, operated by the Federal or Provincial agencies, or both, which may now be redundant, if water users are keeping appropriate and adequate records of use.

2.5 WATERSHEDS AND AQUIFERS

2.5.1 Location

Nova Scotia is a peninsula and an adjacent island, Cape Breton, all lying between $43^{o}25'$ and $47^{o}15'$ N latitude and $50^{o}40'$ and $66^{o}25'$ E longitude. It has an area exceeding 55,000 sq. kilometres (21,425 sq. miles) surrounded by more than 8200 kilometres (5100 miles) of shoreline and is joined to New Brunswick along a 32 kilometre (20 miles) long border. The ocean bodies around the province are Northumberland Strait, Gulf of St. Lawrence, Atlantic Ocean, Gulf of Maine, Bay of Fundy and Chignecto Bay.

Nova Scotia is part of the Appalachian Geosincline, being more than 70% uplands, most of which is forested.

2.5.2 Physiography

Nova Scotia contains several distinct physiographic areas, ten on mainland Nova Scotia, and three fragmented areas on Cape Breton Island. The causes for this unique variety range broadly through submersion and sedimentation; glaciation; and uplifting, folding intrusion and erosion. The following is a brief overview of each of the areas, as shown in Appendix E-1 "Physiographic Regions of Nova Scotia".

Mainland Nova Scotia:

1. Southern Uplands

This area covers the southern half of the Province. It is composed of slate, greywacke, quartzite and granite. The maximum elevation is approximately 275 metres at the north edge from which it falls below sea level forming a coastal shelf.

2. North Mountain-Annapolis Valley:

This area stretches along the Bay of Fundy from Cape Blomidon to the end of the Digby Neck. It consists of lavas and sediments of the Triassic age, in the form of a trough and ridge, and running out under the Minas Channel and Bay of Fundy. The elevation along the North Mountain is relatively constant along its length, with an approximate maximum of 230 metres.

3. Minas Lowlands:

Running along the southern side of the Minas Basin from Windsor to beyond Truro and in as far as the northern edge of the Musquodoboit River, this area consists of eroded Windsor and Horton formations of the Lower Carboniferous Age. Its greatest elevation is approximately 110 metres.

4. Cobequid Lowlands:

Bordering the Minas Basin and Cobequid Mountains from Parrsboro to Truro, this area is an extension of the North Mountain-Annapolis Valley Area (#2), beyond the Minas Basin, having the same formation. The highest point is about 100 metres.

5. Cobequid Uplands:

This area encompasses the Cobequid Mountains from Cape D'Or towards Pictou. It features an uneven terrain reaching a maximum elevation of approximately 275 metres composed of the slates interlaced with a variety of intrusive rocks.

6 & 7. Northumberland Lowlands and Pictou Basin

Bounded by The Northumberland Strait and the Cobequid Mountain, and the northwest portion of Pictou County, these areas consist of sediments of the Carboniferous Age overlaid with tills. They are relatively flat with the main difference being the drainage directions. Both areas have a maximum elevation of approximately 100 metres.

8. Pictou-Antigonish Highlands:

This area lies in the eastern portions of Pictou and Antigonish Counties, up to the Strait of Canso, in the shape of a horseshoe with a maximum elevation of about 250 metres. It contains folded and faulted pre-carboniferous rock and is very hilly.

9. Antigonish Lowlands:

Lying in the centre of the Pictou-Antigonish Highlands horseshoe, this area consists primarily of Windsor Group rocks similar to those in the Minas Lowlands, and is quite flat, although it has a maximum elevation of approximately 200 metres.

10. St. Mary's Graben:

This area is in the centre of the eastern half of the N. S. mainland. It contains mostly rock of the Horton Group, faulted to the north and south and downthrown with a relatively level surface.

11. Cape Breton Island:

Cape Breton is made up of three main areas with the highest point rising to approximately 510 metres These areas are interlaced throughout the island and listed as follows:

A. Cape Breton Uplands

These are composed of Precambrian sediments and intrusive rock ranging from granites to gabbros, and underlie most of the island.

B. Cape Breton Coal Basin
These areas are made up of Pennsylvanian sediments with some deposits of coal.

C. Cape Breton Lowlands
Similar to the Minas Lowlands, these areas are composed of rock from the Windsor and Horton Groups.

2.5.3 Geology and Groundwater

Groundwater regions in Nova Scotia, delineated in Appendix E-2- "Groundwater Regions of Nova Scotia" are based on the possibility of conditions, in various bedrock and surficial aquifers, for the occurrence of groundwater. Three regions are identified, as listed below.

Groundwater Region 1: Igneous and Metamorphic Rocks. Groundwater is available in these rock types through fractures and joints, and along fault and contact zones. No distinction is made here between the igneous or sedimentary origins of the metamorphic rocks, neither is distinction made between the metamorphic and plutonic rocks. These all have similar characteristics in their abilities to store and transmit water.

Groundwater Sub-region 1A: Plutonic Igneous Rocks.

Groundwater Sub-region 1B: Metamorphic Rocks.

Groundwater Region 2: Sedimentary Rocks.
This region is divided into subregions 2A and 2B as follows:

Groundwater Sub-Region 2A: Carbonate Rocks.
The porosity and permeability of carbonate rocks may range from low values where rock is slightly fractured to extremely high values where extensive fracturing and solution have taken

place. Where carbonates outcrop at the surface, the aquifers are highly vulnerable to contamination. The enlarged pore spaces in the rock provide easy movement for contaminants and very little treatment by natural filtration. For this reason carbonate rocks are singled out in a separate sub-region.

Groundwater Sub-Region 2B: Remainder of Sedimentary Rocks.
Sedimentary rocks can have intergranular permeability and, like igneous and metamorphic rocks, fracture and joints permeability permit movement of groundwater along fault and contact zones. The importance of intergranular permeability relative to fracture depends on the degree of consolidation of the rock and the resulting size of void areas between the grains and the degree of fracturing.

Groundwater Region 3. Deposits.
Most of the Province is overlaid by glacial deposits. These deposits are the result of glaciation during the Ice Ages and range in thickness from nothing to as much as 30 metres (100 feet). The glacial retreats transported some of these materials again by means of melt waters. The final result is a wide variety of moraines, eskers, and glacial and fluvial outwash.

2.5.4 Climate

The climate of Nova Scotia is rarely extreme. Only occasionally do temperatures rise above 32°C in summer or fall below -18°C in winter. As such, the climate is tempered by the almost completely surrounding ocean and by the influence of the Gulf Stream which runs northeasterly and parallel to the Atlantic Coast.

The mean daily maximum temperature for the months of July and August are: Halifax 22°C; Truro 23°C; Sydney 23°C; and

Yarmouth 21°C. The January-February mean daily minimums for these places are -8°C, -11°C, -9°C and -6°C respectively.

The average yearly rainfall range is 810-1370 millimetres. The lowest average snowfall amounts of 125-200 centimetres per year, are found near the mouth of the Bay of Fundy, along the Atlantic Coast of Nova Scotia, near the shores of the Minas Basin and near the eastern end of the Northumberland Strait. Average amounts of 200 to 300 centimetres fall in most other sections of the mainland while averages in excess of 360 centimetres per year are found over the Cape Breton Highlands. The heaviest snowfall is during the months of December, January, February and March, with light snowfalls in November and April.

The frost-free season ranges from less than 100 days in some interior sections of Nova Scotia to over 160 days along the Atlantic Coast.

Fog is common in late spring and early summer, particularly in coastal areas. Partly for this reason the region reports an average of less sunshine than most of southern Canada.

Thunderstorms are rare, even in summer, and seldom reach the intensity experienced in more continental areas.

2.5.5 Drainage Basins

Approximately 5% of the land area of Nova Scotia is covered by water in the form of lakes or rivers, representing a total of 2408 sq. kilometres (930 sq. miles). The periphery of the province is interlaced with innumerable inlets and small rivers, while many larger rivers flow from the interior.

A series of maps showing the watersheds in the province were produced in 1982 by Maritime Resource Management Services. These maps are at a scale of 1:50,000 and indicate the delineations of primary, secondary and tertiary watersheds along with their total areas and water covered areas. A total of 46 primary watersheds in Nova Scotia are shown on these maps, and listed in Table 2.1. A map of the major rivers and drainage divides is shown on Appendix E-3 "Hydrolgic Zones and Major Rivers of Nova Scotia".

TABLE 2.1
PRIMARY WATERSHEDS IN NOVA SCOTIA

Watershed	Area (Square Kilometres)			
No.	Major Rivers	Land	Water	Total
-	Isle Madame	145	6	151
1BT	Missaguash	45	29	74
1DA	Meteghan	570	41	611
B	Sissiboo and Bear	1349	79	1428
C	Annapolis	2209	70	2290
D	Gaspereau	1316	58	1375
E	St. Croix	1306	61	1368
F	Kennetcook	1116	9	1125
G	Shubenacadie and Stewiacke	2540	73	2614
H	Salmon and Debert	1164	4	1168
J	Economy	790	3	793
K	Parrsboro	856	2	858
L	Kelley and Maccan and Hebert	1295	9	1304
M	Tidnish and Shinimikas	475	4	479
N	Philip and Wallace	1475	19	1494
O	John	1111	6	1117
P	East and Middle and West (Pictou)	1190	7	1197
Q	French	735	1	736
R	South and West (Antigonish)	898	9	907
S	Tracadie	580	6	586
1EA	Tusket	1982	194	2177
B	Barrington and Clyde	1243	79	1423
C	Roseway and Sable and Jordan	1350	84	1435
D	Mersey	2690	339	3030
E	Herring Cove and Medway	1845	166	2012
F	LaHave	1611	89	1700
G	Gold	972	57	1029
H	East and Indian	695	69	765
J	Sackville	924	71	996
K	Musquodoboit	1316	93	1409
L	Tangier	974	111	1086
M	East (Sheet Harbour)	914	74	988
N	Liscomb	1136	66	1202
O	St. Marys	1505	43	1549
P	Country Hbr.	550	18	569
Q	New Hbr. and Salmon (Guys.)	1019	70	1089
R	Clam Hbr. and St. Francis	517	14	532

TABLE 2.1 (Continued)
PRIMARY WATERSHEDS IN NOVA SCOTIA

Watershed	Area (Square Kilometres)			
No.	Major Rivers	Land	Water	Total
1FA	Inhabitants	1193	10	1204
B	Margaree	1308	67	1375
C	Cheticamp	802	3	806
D	Wreck Cove	1057	15	1072
E	Indian	882	7	890
F	North and Baddeck and Middle	764	2	767
G	Denys and Big	792	2	794
H	Grand	739	33	772
J	Salmon and Mira	2779	134	2914
TOTAL	AREAS	52822	2408	55230

Adapted from "Nova Scotia Watersheds" MRMS for NSDOE (1981)

CHAPTER 3

EXISTING NETWORKS

3.1 DESCRIPTIONS

The overall hydrologic network is comprised of numerous sub networks which provide essential information on the various segments of the hydrologic cycle. The database consists of the active and discontinued data collection sites. In this chapter, networks will be outlined and, where possible, displayed on maps. The operating agreement between the Federal and Provincial governments, as it pertains to the establishment, operation and maintenance of the hydrometric network in the Province of Nova Scotia, is summarized. The guidelines established by the World Meteorological Organization (W.M.O.) and standards used by the United States Geological Survey (U.S.G.S.) for the establishment of a hydrometric/ hydrologic network are summarized for comparative reference.

The Federal and Provincial Governments are directly involved in the collection of various types of data pertaining to or affected by the elements of the hydrologic cycle. Some of these data are collected in conjunction with other data. Water quality and suspended sediment, which are associated with water discharge as their transport medium, are collected at common sites with discharge. However, much of the other data, i.e. meteorological data, are collected at sites, which do not directly pertain to any other network. These data are collected by various agencies for their own perceived needs.

3.1.1 Existing Surface Water Stations

Surface water stations measure the water level of a lake or stream against some referenced datum elevation, local or Geodetic. However, with the exception of the water level station 01ED006, Kejimkujik Lake, all of the 53 active hydrometric stations listed in Table 3.1 are used to measure the discharge passing the station location.

These stations have been in operation for periods ranging from one to 69 years. Some have been operated continuously, others seasonally. Each has been monitored by a continuous recording gauge and/or a manually read staff gauge. The streamflow, which the gauge monitors, may be relatively free from man's influence and classified as a "natural" flow station, or it may be controlled by dams or diversions and thus be classed as "regulated".

Appendices E-4, Active (1983) Hydrometric Stations on Natural Watersheds, and E-5, Active (1983) Hydrometric Stations on Regulated Watersheds, show the locations of the active hydrometric network stations operating as of December 31, 1983, and the size of the drainage area above each hydrometric station.

3.1.2 Discontinued Surface Water Stations

Operation of a station may be discontinued for various reasons, including the completion of the project for which it was installed, the inundation of the site due to the establishment of a dam downstream of the site, redundancy of the station and, of course, budget cuts.

The abandonment of a site must be performed under the co-operative federal-provincial agreement, as outlined in the Federal-Provincial Cost Sharing Agreement (1975), thus providing each party with an opportunity to maintain its interest. Table 3.2 lists the hydrometric stations which have been discontinued prior to December 31, 1983. Appendix E-6 "Discontinued Hydrometric Stations" shows the locations of the discontinued stations. The exact reason for the discontinuance of stations

ACTIVE HYDROMETRIC GAUGING STATIONS IN NOVA SCOTIA TO 1983

STATION NUMBER	DRAINAGE AREA (KM2)	PERIOD AND TYPE OF RECORD(1)	STATION NAME
01DA001	167	6483QRC	METEGHAN RIVER NEAR METEGHAN RIVER
01DC005	546	6383QRC	ANNAPOLIS RIVER AT WILMOT
01DC007	1020	8383QRC	ANNAPOLIS RIVER AT LAWRENCETOWN
01DD004	8.81	6683QRC	SHARPE BROOK AT LLOYDS
01DG003	96.9	2135QMC 3683QRC	BEAVER RIVER NEAR KINSAC
01DG006	389	6464QMM 7481QMC 8283QRC	SHUBENACADIE RIVER AT ENFIELD
01DG007	106	7474QMM 8383QMM	SHUBENACADIE RIVER AT LAKE THOMAS
01DG017	26.7	8383QMM	POWDER MILL LAKE BROOK NEAR WAVERLEY
01DG018	73.3	7783QRC	PEMBROKE RIVER AT GLENBERVIE
01DG035	76.1	7474QMM 8383QMM	SHUBENACADIE RIVER AT OUTLET LAKE WILLIAM
01DG041	2.58	8383QMM	MUDDY POND BROOK AT WAVERLEY
01DH003	9.07	6583QRC	FRASER BROOK NEAR ARCHIBALD
01DH004	202	7683QRC	NORTH RIVER AT NORTH RIVER
01DH005	287	7783QRC	SALMON RIVER AT UNION
01DL001	63.2	6983QRC	KELLEY RIVER (MILL CREEK) AT EIGHT MILE FORD
01DN004	298	6483QRC	WALLACE RIVER AT WENTWORTH CENTRE
01DO001	249	6583QRC	RIVER JOHN AT WELSFORD
01DP004	92.2	6566QMC 6783QRC	MIDDLE RIVER AT ROCKLIN
01DR001	177	1717QMC 1818QMS 1925QMC 2626QMS 2733QMC	SOUTH RIVER AT ST. ANDREWS
"	"	6683QRC	" "
01DR003	64.2	7878QMC 7983QRC	RIGHTS RIVER NEAR ANTIGONISH
01EA003	1070	2965QMC 6683QRC	TUSKET RIVER AT WILSON'S BRIDGE
01EC001	495	1517QMS 1864QMC 6583QRC	ROSEWAY RIVER AT LOWER OHIO
01ED005	723	6883QRC	MERSEY RIVER BELOW GEORGE LAKE
01ED006	-	6983HRC	KEJIMKUJIK LAKE
01ED007	295	6883QRC	MERSEY RIVER BELOW MILL FALLS
01ED009	8.74	8383QMM	ROGERS BROOK NEAR JAKES LANDING

(1) PERIOD OF RECORD IS FORMATTED AS FOLLOWS

STARTING YEAR	2 DIGITS
LAST YEAR OF DATA	2 DIGITS
TYPE OF STATION	Q-DISCHARGE,H-STAGE
TYPE OF GAUGE	M-MANUAL,R-RECORDING
TYPE OF OPERATION	C-CONTINUOUS,S-SEASONAL,M-MISCELLANEOUS

TABLE 3.1

Continued...

ACTIVE HYDROMETRIC GAUGING STATIONS IN NOVA SCOTIA TO 1983

STATION NUMBER	DRAINAGE AREA (KM2)	PERIOD AND TYPE OF RECORD(1)		STATION NAME
01EE001	1390	1528QMC	2983QRC	MEDWAY RIVER AT CHARLESTON
01EE004	143	8183QRC		WESTFIELD RIVER NEAR NORTH BROOKFIELD
01EE005	16.7	8183QRC		MOOSE PIT BROOK AT TUPPER LAKE
01EE006	56.5	8183QRC		ROUND LAKE BROOK AT ROUND LAKE
01EE007	7.45	8383QMM		WHITEBURN BROOK BELOW POLLOCK LAKE
01EF001	1250	1548QMC	4983QRC	LA HAVE RIVER AT WEST NORTHFIELD
01EG002	370	6583QRC		GOLD RIVER AT MOSHER'S FALLS
01EH003	26.9	2570QMC	7183QRC	EAST RIVER AT ST. MARGARETS BAY
01EJ001	146	1616QMC	7083QRC	SACKVILLE RIVER AT BEDFORD
01EJ004	13.1	8083QRC		LITTLE SACKVILLE RIVER AT MIDDLE SACKVILLE
01EJ005	15.1	8283QRC		MCINTOSH RUN AT HERRING COVE ROAD
01EK001	650	1555QMC	5683QRC	MUSQUODOBOIT RIVER AT CRAWFORD FALLS
01EN002	389	6283QRC		LISCOMB RIVER AT LISCOMB MILLS
01EO001	1350	1555QMC	5683QRC	ST. MARYS RIVER AT STILLWATER
01ER001	45.1	5783QRC		CLAM HARBOUR RIVER NEAR BIRCHTOWN
01FA001	193	6583QRC		RIVER INHABITANTS AT GLENORA
01FA003	26.7	6983QRC		NORTH LITTLE RIVER BELOW BEAVER DAM LAKE
01FB001	368	1641QMC	4283QRC	NORTHEAST MARGAREE RIVER AT MARGAREE VALLEY
01FB003	357	1866QMC	6783QRC	SOUTHWEST MARGAREE RIVER NEAR UPPER MARGAREE
01FB006	37.8	7883QRC		LAKE O'LAW BROOK AT EGYPT ROAD
01FC002	190	5883QRC		CHETICAMP RIVER ABOVE ROBERT BROOK
01FC003	37.0	7883QRC		CHETICAMP RIVER BELOW ARTEMISE BROOK
01FE002	125	6066QMC	6783QRC	INDIAN BROOK AT INDIAN BROOK
01FH001	120	2059QMC	6083QRC	GRAND RIVER AT LOCH LOMOND
01FJ001	199	6583QRC		SALMON RIVER AT SALMON RIVER BRIDGE
01FJ002	17.2	7883QRC		MCASKILL BROOK NEAR BIRCH GROVE
01FJ003	23.3	8383QMM		SOUTHWEST BROOK NEAR COLLEGE OF CAPE BRETON

(1) PERIOD OF RECORD IS FORMATTED AS FOLLOWS

STARTING YEAR	2 DIGITS
LAST YEAR OF DATA	2 DIGITS
TYPE OF STATION	Q-DISCHARGE,H-STAGE
TYPE OF GAUGE	M-MANUAL,R-RECORDING
TYPE OF OPERTATION	C-CONTINUOUS,S-SEASONAL,M-MISCELLANEOUS

TABLE 3.1 Concluded

DISCONTINUED HYDROMETRIC GAUGING STATIONS IN NOVA SCOTIA TO 1983

STATION NUMBER	DRAINAGE AREA (KM2)	PERIOD AND TYPE OF RECORD(1)	STATION NAME
01DB001	596	1516QMS	SISSIBOO RIVER NEAR WEYMOUTH
01DB002	193	1515QMM 1651QMC	BEAR RIVER EAST BRANCH AT BEAR RIVER
01DC001	124	1517QMS 1819QMC	ALLAIN RIVER AT LEQUILLE
01DC002	298	1620QMC	NICTAUX RIVER AT NICTAUX FALLS
01DC003	94.5	1618QMS 1919QMC 2020QMS 2149QMC	PARADISE BROOK NEAR PARADISE
01DC006	119	6579QRC	SOUTH ANNAPOLIS RIVER AT MILLVILLE
01DD001	370	1517QMC 1818QMS 1920QMC	GASPEREAU RIVER AT MARTIN'S BRIDGE
01DD003	370	1517QMC 1818QMS 1920QMC	GASPEREAU RIVER AT MILLRACE DIVERSION
01DE002	228	1516QMC 2534QRC	ST. CROIX RIVER AT HARTVILLE
01DF001	179	7576QMS	KENNETCOOK RIVER AT KENNETCOOK
01DG001	420	1516QMS 1726QMC	STEWIACKE RIVER NEAR UPPER STEWIACKE
01DG002	46.4	1516QMS 1821QMC	FALL RIVER AT WAVERLEY
01DG004	7.51	5960QMS	BENNERY BROOK NEAR BENNERY LAKE
01DG005	401	6464QMM	STEWIACKE RIVER AT UPPER STEWIACKE
01DG019	6.22	7878QMM	BLACK BROOK AT OLDHAM
01DG020	28.0	7878QMM	BENNERY BROOK SITE NO. 1
01DG021	0.23	7878QMM	BENNERY BROOK SITE NO. 2
01DG022	1.35	7878QMM	BENNERY BROOK SITE NO. 3
01DG023	7.77	7878QMM	BENNERY BROOK SITE NO. 4
01DG024	14.5	7878QMM	BENNERY BROOK SITE NO. 6
01DG025	2.85	7878QMM	BENNERY BROOK SITE NO. 5
01DG026	8.55	7878QMM	BENNERY BROOK SITE NO. 7
01DG027	5.70	7878QMM	BENNERY BROOK SITE NO. 8
01DG028	2.33	7878QMM	BENNERY BROOK SITE NO. 9
01DG029	2.59	7878QMM	BENNERY BROOK SITE NO. 10
01DG030	0.49	7878QMM	BENNERY BROOK SITE NO. 11
01DG031	1.06	7878QMM	BENNERY BROOK SITE NO. 14
01DG032	0.34	7878QMM	BENNERY BROOK SITE NO. 12
01DG033	0.36	7878QMM	BENNERY BROOK SITE NO. 15
01DH001	316	1718QMS 1924QMC 2526QMS 8282QMM	SALMON RIVER AT VALLEY
01DH002	363	6472QRC	SALMON RIVER AT MURRAY
01DJ001	93.8	2026QMC	GREAT VILLAGE RIVER NEAR GREAT VILLAGE
01DJ003	130	2327QMC	ECONOMY RIVER NEAR ECONOMY

(1) PERIOD OF RECORD IS FORMATTED AS FOLLOWS

STARTING YEAR	2 DIGITS
LAST YEAR OF DATA	2 DIGITS
TYPE OF STATION	Q-DISCHARGE,H-STAGE
TYPE OF GAUGE	M-MANUAL,R-RECORDING
TYPE OF OPERATION	C-CONTINUOUS,S-SEASONAL,M-MISCELLANEOUS

TABLE 3.2

Continued...

DISCONTINUED HYDROMETRIC GAUGING STATIONS IN NOVA SCOTIA TO 1983

STATION NUMBER	DRAINAGE AREA (KM2)	PERIOD AND TYPE OF RECORD(1)	STATION NAME
01DJ004	8.81	7879QRC	FIVE ISLANDS RIVER NEAR BRITISH LAKE
01DL002	98.4	7779QMC	MACCAN RIVER AT EAST SOUTHAMPTON
01DN001	370	1516QMS	RIVER PHILIP AT OXFORD ELECTRIC LIGHT PLANT
01DN002	228	1723QMC	RIVER PHILIP NEAR RIVER PHILIP POST OFFICE
01DN003	394	2325QMC 2626QMS 2730QMC 3132QMS 3333QMC	WALLACE RIVER AT HOWARD'S MILL
01DN005	114	7779QMC	WALLACE RIVER AT WENTWORTH
01DN006	43.0	7779QMC	ROARING RIVER AT WESTCHESTER STATION
01DN007	105	7779QMC	RIVER PHILIP AT COLLINGWOOD CORNER
01DN008	46.9	7779QMC	WEST RIVER PHILIP AT COLLINGWOOD CORNER
01DP001	246	1515QMM	EAST RIVER (PICTOU) EAST BRANCH AT EUREKA
01DP002	140	1516QMS	EAST RIVER (PICTOU) WEST BRANCH AT EUREKA
01DP003	404	3636QMM 6465QMC	EAST RIVER AT STELLARTON
01DP005	204	6666QMC	MIDDLE RIVER AT ALMA
01DQ001	48.2	7777QMS	EAST FRENCH RIVER NEAR MERIGOMISH
01DR002	52.1	7879QMC	JAMES RIVER NEAR JAMES RIVER
01EA001	1450	1529QMC	TUSKET RIVER AT TUSKET FALLS
01EA002	337	2029QMC	TUSKET RIVER (WEST BRANCH) AT REYNARD BRIDGE
01ED001	1550	1515QMS 1620QMC 2729QMC	MERSEY RIVER AT INDIAN GARDENS
01ED002	1940	3031QRC 3232QMM 3354QRC	MERSEY RIVER AT LOWER GREAT BROOK FALLS
01ED003	1960	5579QRC	MERSEY RIVER AT MILTON
01ED004	1670	4068HMC	LAKE ROSSIGNOL AT UPPER LAKE FALLS
01ED008	1.09	7981QRC	BEAVERSKIN BROOK AT BEAVERSKIN LAKE
01EE002	342	1619QMM 2025QMC 2743QMC 4482QRC	MEDWAY RIVER AT HARMONY MILLS
01EE003	59.6	2848QRC	HERRING COVE BROOK NEAR BROOKLYN
01EF003	728	1517QMC 6379QRC	LA HAVE RIVER ABOVE MORGAN'S FALLS
01EG001	373	1616QMC 1717QMM	GOLD RIVER NEAR CHESTER BASIN
01EH001	91.9	1517QMC	NORTHEAST RIVER AT ST. MARGARET'S BAY
01EH002	176	1520QMC	INDIAN RIVER AT ST. MARGARET'S BAY
01EH004	25.1	7778QMM	LITTLE EAST RIVER CHESTER NEAR EAST RIVER POINT
01EH005	28.5	7778QMM	LITTLE EAST RIVER CHESTER AT ROUS POINT
01EJ002	36.0	7073QMC	KEARNEY RUN AT MILLVIEW
01EK002	52.3	7171QMS	LITTLE RIVER AT PETPESWICK INLET

(1) PERIOD OF RECORD IS FORMATTED AS FOLLOWS

STARTING YEAR	2 DIGITS
LAST YEAR OF DATA	2 DIGITS
TYPE OF STATION	Q-DISCHARGE,H-STAGE
TYPE OF GAUGE	M-MANUAL,R-RECORDING
TYPE OF OPERATION	C-CONTINUOUS,S-SEASONAL,M-MISCELLANEOUS

TABLE 3.2

Continued...

DISCONTINUED HYDROMETRIC GAUGING STATIONS IN NOVA SCOTIA TO 1983

STATION NUMBER	DRAINAGE AREA (KM2)	PERIOD AND TYPE OF RECORD(1)	STATION NAME
01EK003	334	7483QRC	MUSQUODOBOIT RIVER NEAR MIDDLE MUSQUODOBOIT
01EK004	141	7483QRC	MUSQUODOBOIT RIVER NEAR UPPER MUSQUODOBOIT
01EM001	526	1523QMC	EAST RIVER SHEET HARBOUR AT MALAY FALLS
01EN001	386	1618QMC	LISCOMB RIVER AT LISCOMB FALLS
01EO002	49.2	1516QMS 1717QMC 1823QMS 2426QMC	ARCHIBALD BROOK AT STILLWATER
01EO003	282	6579QRC	EAST RIVER ST. MARYS AT NEWTOWN
01ER002	23.8	5860QRC	ST. FRANCIS RIVER AT GOOSE HARBOUR LAKE
01FA002	41.4	6768QRC	LITTLE RIVER NEAR PORT RICHMOND
01FB002		1818HMC	SOUTHWEST MARGAREE RIVER AT MARGAREE FORKS
01FB004	311	2728QMC	SOUTHWEST MARGAREE RIVER AT SCOTSVILLE
01FB005	6.22	6679QRC	APRIL BROOK AT GILLISDALE
01FC001	49.2	5877QRC	CHETICAMP RIVER BELOW CHETICAMP LAKE
01FD001	27.7	5664QMC 6577QRC	WRECK COVE BROOK NEAR WRECK COVE
01FE001	82.4	6077QRC	INDIAN BROOK NEAR MATHESON'S LAKE

(1) PERIOD OF RECORD IS FORMATTED AS FOLLOWS

STARTING YEAR	2 DIGITS
LAST YEAR OF DATA	2 DIGITS
TYPE OF STATION	Q-DISCHARGE,H-STAGE
TYPE OF GAUGE	M-MANUAL,R-RECORDING
TYPE OF OPERATION	C-CONTINUOUS,S-SEASONAL,M-MISCELLANEOUS

TABLE 3.2 Concluded

can only be determined for the stations discontinued in the last few years. Table 3.3 lists stations which have been discontinued, the purpose for which they were established and the reason for discontinuance.

3.1.3 Water Quality Network

The Water Survey of Canada Division collects water quality samples from some sites at or close to the hydrometric stations in the network. The required sampling schedule thus can be maintained and cost savings can be realized by avoiding separate sampling field trips. Water quality stations can be split into three categories: Overview, Long Range Transport Aerial Pollutants (LRTAP) and Radioisotopes, according to the uses to which the samples are applied. Some stations such as on the Annapolis River are used for two categories. Overview stations are sampled bi-monthly, and are used for monitoring any long term changes in the chemistry of the runoff in the Province. The LRTAP stations are sampled monthly in support of acid rain research. The radioisotope stations are sampled monthly at the two locations which might be first influenced should problems exist with the upwind nuclear establishment, i.e., Point Lepreau nuclear reactor and the Glace Bay Heavy Water Plant. Any other sampling is performed as an ad hoc or project oriented basis by Water Quality Branch staff to meet specific but non-network requirements.

Table 3.4 lists the water quality stations, their types, and companion hydrometric station numbers where applicable. Table 3.5 lists the water quality parameters analysed from overview and LRTAP stations.

3.1.4 Suspended Sediment Sampling Stations

Suspended sediment sampling began in Nova Scotia in 1965. In total, 9 hydrometric stations have been used to sample suspended sediment. These are listed in Table 3.6.and shown in Appendix

TABLE 3.3
SOME RECENTLY DISCONTINUED STATIONS AND THE REASON FOR DISCONTINUANCE

Station No.	Purpose of Station	Reason for Discontinuance
01DC006	To check turbine rating of the Town of Berwick Power Plant	Project complete
01DF001	Water Quality measurement site for Department of Health	Poor control
01DH002	Network station	Control changed by channel improvement
01DJ004	Study for new water supply for Town of Springhill	Supply found elsewhere
01DP005	Causeway Study, Scott Paper near Pictou	Site flooded out
01DQ001	Freshwater input into Oyster beds	Project complete
01DR002	Water supply for Antigonish	Stream controlled
01ED003	Network station	Cost sharing reduced
01ED008	Water quality and acid rain	Not hydrometrically possible
01EE002	Power - cost sharing station	Cost sharing terminated
01EF003	Fisheries (Federal)	Funding Terminated
01EH004	Construction at plant	Study complete
01EH005	Construction at plant	Study complete
01EJ002	Study of input at Bedford Basin	Study complete
01EK002	Fish study (Federal)	Study complete
01EK003	Agriculture study (Federal-Provincial)	Study complete
01EK004	Agriculture study (Federal-Provincial)	Study complete
01EO003	Fisheries (Federal)	Funding Terminated
01FA002	Water supply	No water after dam built
01FB005	International Hydrological Decade	Ran allotted time
01FC001	Wreck Cove hydroelectric project	Project complete
01FD001	Wreck Cove hydroelectric project	Project complete
01FE001	Wreck Cove hydroelectric project	Project complete

ACTIVE WATER QUALITY SAMPLING SITES IN NOVA SCOTIA TO 1983

WSC STATION NUMBER	NAQUADAT* STATION NUMBER	YEAR DATA BEGAN	STATION TYPE			STATION NAME
			OVERVIEW	LRTAP#	RADIO ISOTOPE	
01DA001	00NS01DA0001	1969		X		METEGHAN RIVER NEAR METEGHAN RIVER
01DC005	00NS01DC0001	1967	X		X	ANNAPOLIS RIVER AT WILMOT
N/A	00NS01DE0001	1971		X		AVON RIVER AT POWER PLANT
N/A	00NS01DG0008	1978	X			SHUBENACADIE RIVER AT ELMSDALE
01DL001	00NS01DL0009	1970		X		KELLEY RIVER (MILL CREEK) AT EIGHT MILE FORD
01DN004	00NS01DN0001	1966	X	X		WALLACE RIVER AT WENTWORTH CENTRE
01EA003	00NS01EA0001	1965		X		TUSKET RIVER AT WILSON'S BRIDGE
01EC001	00NS01EC0005	1971		X		ROSEWAY RIVER AT LOWER OHIO
01ED009	00NS01ED0030	1983		X**		ROGERS BROOK NEAR JAKES LANDING
01EE001	00NS01EE0001	1965	X	X		MEDWAY RIVER AT CHARLESTON
01EE007	00NS01EE0007	1983		X**		WHITEBURN BROOK BELOW POLLOCK LAKE
01EF001	00ND01EF0002	1971		X		LA HAVE RIVER AT WEST NORTHFIELD
01EN002	00NS01EN0002	1971		X		LISCOMB RIVER AT LISCOMB MILLS
01EO001	00NS01EO0001	1965	X	X		ST. MARYS RIVER AT STILLWATER
01ER001	00NS01ER0001	1969		X		CLAM HARBOUR RIVER NEAR BIRCHTOWN
01FB001	00NS01FB0001	1965	X			NORTHEAST MARGAREE RIVER AT MARGAREE VALLEY
01FJ001	00NS01FJ0001	1969	X			SALMON RIVER AT SALMON RIVER BRIDGE
01FJ002	00NS01FJ0021	1981			X	MCASKILL BROOK NEAR BIRCH GROVE

* - NAQUADAT - National Water Quality Data Storage and Retrieval System, operated by the Water Quality Branch, Inland Waters Directorate, Environment Canada

** - Samples collected by contractor

# - LRTAP - Long Range Transport Aerial Pollution

TABLE 3.4

TABLE 3.5

WATER QUALITY PARAMETER LIST FOR OVERVIEW AND LRTAP STATIONS

	Parameter		NAQUADAT Code
Field	Temperature		01061F
	pH		10301F
	Diss. Oxygen (Hach)		88600F
LAB	pH		10301L
	Sp. Copnd		02041L
	Turtbidity		02073L
	Alkalinity (Total & Gran)		10101L & 10110L
	Colour		02011L
	Calcium		20110L
	Magnesium,		12107L
	Potassium		19103L
	Sodium		11103L
	Chloride		17205L
	Sulphate (MTB)		16304L
	Sulphate (IC)		16309L
	Phosphorus Total		15413P
	Copper	Extractable	29305P
	Zinc	Extractable	30309P
	Cadmium	Extractable	48302P
	Lead	Extractable	82302P
	Aluminium	Extractable	13305P
	Iron	Extractable	26304P
	Manganese	Extractable	25304P
	DOC		06107L
	Humic Acid		06581L
	Nitrate & Nitrite		07110L
	Total Nitrogen		07601L
	Fluoride		09106L
	Silica		14102L

TABLE 3.6

ACTIVE AND DISCONTINUED SUSPENDED SEDIMENT MONITORING STATIONS IN NOVA SCOTIA

Station Number	Active	/Discontinued	Station Name	Period of Record
01DC005	A		Annapolis River at Wilmot	1967 - 1983
01DD004		D	Sharpe Brook at Lloyds	1968 - 1974
01DG018	A		Pembroke River at Glenbervie	1978 - 1983
01DH002		D	Salmon River at Murray	1967 - 1972
01DH003		D	Fraser Brook near Archibald	1966 - 1975
01DL001	A		Kelley River (Mill Creek) at Eight Mile Ford	1971 - 1983
01DP004	A		Middle River at Rocklin	1969 - 1983
01FB005		D	April Brook at Gillisdale	1968 - 1979
01FJ001		D	Salmon River at Salmon River Bridge	1976 - 1977

E-7 "Active and Discontinued Suspended Sediment Samples Station". The small number of stations does not constitute a core of network stations. However, a study presently being conducted under contract, Washburn & Gillis (1985) is assessing this program in light of what the users of the data perceive to be most useful.

3.1.5 Groundwater Measurement Stations

The fluctuation of the groundwater level is important in establishing the depletion and recovery of the groundwater and ultimately an estimate of the available resources as a water supply. The groundwater network was established and is operated by the Nova Scotia Department of the Environment. The network operates more on a basis of project need than as an overview network.

Table 3.7 contains a list of the active groundwater monitoring wells, with their respective periods of record, Appendix E-8, "Active (1983) Groundwater Monitoring Well Network", shows the location of the wells. Table 3.8 and Appendix E-9, "Abandoned Groundwater Monitoring Well Network", list and show the discontinued groundwater monitoring wells respectively. It should be noted that no station has records prior to 1965, and that water quality analyses at the active sites has not yet begun.

A Groundwater Quality Monitoring Network was operated in 1972-73 with data stored on the NAQUADAT System.

3.1.6 Snow Course Data Network

The water content of the snow on the ground has been measured at specific sites as shown in Appendix E-10" Snow Course Sampling Sites". These data may be of use to those working in flood forecasting, hydroelectric power, water supply and agriculture. It provides an indication of the amount of water stored as snow

TABLE 3.7

GROUNDWATER MONITORING WELLS (ACTIVE)

Station Number	Station Name	Period of Record(s)
001	Coldbrook	1965-1984
002	Truro	1966-1984
003	Greenwood	1967-1984
004	Fraser Brook	1967-1974, 1976-1984
005	Wilmot	1967-1984
007	Murray Siding	1969-1970, 1972-1972, 1974-1984
009	Wolfville 1	1970-1984
010	Wolfville 2	1970-1970, 1972-1984
011	Sharpe Brook	1971-1984
012	Wolfville 3	1971-1974, 1976-1984
013	Truro 420	1974-1974, 1976-1984
014	Truro 421	1971-1984
015	Truro 422	1971-1984
016	Sable Island 19	1971-1974, 1976-1978, 1984-1984
017	Sable Island 50	1975-1978, 1984-1984
018	Sable Island 47	1972-1974, 1984-1984
021	Wittenberg Farm	1975-1978, 1980-1984
022	Lower Canard	1974-1984
024	Three Brooks 5	1975-1984
025	Three Brooks 4	1975-1984
028	Monastery	1976-1979, 1982-1984
042	Sable Island 17	1972-1972, 1984-1984
043	Lawrencetown L3	1978-1984
044	Oakfield Park	1978-1984
045	Durham	1978-1984

TABLE 3.8

GROUNDWATER MONITORING WELLS (DISCONTINUED)

Station Number	Station Name	Period of Record(s)
006	Amherst	1967-1980
008	Gillisdale	1969-1979
020	Mill Village	1974-1978
023	Three Brooks 6	1975-1980
029	Havre Boucher	1976-1977
030	Point Aconi	1976-1979
031	Canning	1965-1969
032	Berwick	1965-1973
033	Sheffield Mills	1967-1970, 1972-1974
034	Oxford	1967-1969
035	Murray Siding	1967-1968
036	Murray Siding	1967-1968
037	Antigonish	1968-1968
038	Antigonish	1968-1969
039	Musquodoboit Harbour	1968-1968
040	Musquodoboit Harbour	1968-1968
041	Musquodoboit Harbour	1968-1968
046	Lawrencetown L1	1979-1979

which would then be available for runoff.

Effective the fall of 1984, only the snow courses at Greenwood and Truro which are measured by staff of the Atmospheric Environment Service will be sampled. The remaining sites, which were sampled by Water Survey of Canada Division technicians, will be discontinued as the Water Resources Branch (IWD) withdraws this service due to a perceived lack of interest by data users.

3.1.7 Evaporation Pan Stations

Evaporation pan data are collected at three sites in Nova Scotia, the experimental farms at Kentville and Nappan, and the climate station at Truro as shown in Appendix E-11 "Active (1983) Evaporation Measurement Stations". While it is obvious that these data are of use to agriculture, they are also used by hydrologists in water balance studies.

3.1.8 Climatological Stations

The Atmospheric Environment Service (AES) of Environment Canada maintains approximately 88 climatological stations in Nova Scotia. There are two types of stations, the principal station for collecting a large variety of data, including synoptic, temperature, precipitation and rate of rainfall, and the secondary stations which normally, although not exclusively, collect only temperature and precipitation. Summaries of the active stations are listed in Tables 3.9 and 3.10, and their locations shown in Appendix E-12 "Active (1983) Climatological Stations". Like the hydrometric station network, some of these stations provide real time information, but most only record daily data that are used to study the long term changes in the climate. These data can be used to study or predict the effects from the climate changes on other activities such as agriculture, silviculture and fisheries.

TABLE 3.9

CLIMATOLOGICAL NETWORK STATIONS (PRINCIPAL)

Station Name	Data Collected	
	Basic Data	Other
Amherst (aut)*	X	
Atlantic Weather Centre		
Eddy Point	X	Sunshine, nipher
Greenwood A	X	Snow Survey, nipher
Halifax Internation A	X	Nipher, Radar
Inverness (aut)*	X	
Sable Island	X	Sunshine, radiation, upper air, air quality, nipher
Shearwater A	X	Sunshine, nipher
Shelburne	X	Sunshine, upper air, nipher
Sydney	X	Sunshine, upper air, snow survey, nipher
Truro	X	Soil temperature, evaporation, sunshine, snow survey, nipher
Truro (aut)	X	
Western Head (aut)*		
Yarmouth A	X	Sunshine, nipher

X - Synoptic, hourly, temperature, precipitation (rain and snow), rate of rainfall, wind, pressure.

* - Precipitation amounts not recorded during winter months.

(auto) - Automatic

TABLE 3.10

CLIMATOLOGICAL NETWORK STATIONS (SECONDARY)

Station Name	Temperature	Precipitation	Other
Argyle Head	X	X	Sunshine
Avon		X	
Baddeck	X	X	
Bear River		X	
Braeshore	X	X	
Bridgewater	X	X	
Cape Sable	X	X	
Charlesville	X	X	Sunshine
Cheticamp	X	X	
Clarence	X	X	
Clifton	X	X	
Collegeville	X	X	
Debert	X	X	
Denning	X	X	
Dickie Brook	X	X	
Digby CKDY	X	X	Wind
Digby Prim Point	X	X	
Ecum Secum	X	X	
Farmington	X	X	
Gisborne Lake			Rate of rainfall (F/P)
Great Village	X	X	
Halifax Citadel	X	X	Wind, radiation
Harmony		X	
Hopewell	X	X	Nipher
Indian Brook		X	
Ingonish Beach	X	X	Rate of rainfall, wind, sunshine, nipher
Jackson	X	X	Rate of rainfall (F/P)
Kemimkujik Park	X	X	
Kelley River IHD			Rate of rainfall (F/P)
Kemptville		X	
Kentville CDA	X	X	Rate of rainfall, soil temperature, evaporation, sunshine, radiation, nipher
Liverpool Big Falls	X	X	
Liverpool Milton	X	X	
Louisbourg	X	X	

F/P - Rainfall recorded by Fisher-Porter gauge at 15 minute intervals. Otherwise a tipping-bucket recorder is used.

TABLE 3.10 (Cont'd)

CLIMATOLOGICAL NETWORK STATIONS (SECONDARY)

Station Name	Temperature	Precipitation	Other
Lower L'Ardoise	X	X	Wind
Lower Meaghers Grant	X	X	
Margaree Forks	X	X	
Meteghan River	X	X	
Middleboro	X	X	
Middle Musquodoboit	X	X	
Mill Village	X	X	Rate of rainfall
Mount Uniacke	X	X	
Nappan CDA	X	X	Evaporation, sunshine, nipher
Northeast Margaree	X	X	
North Mountain			Rate of rainfall
Paradise		X	
Parrsboro	X	X	
Pleasant Bay Grand Anse	X	X	
Pockwock Lake	X	X	
Point de L'Englise	X	X	
Port Hastings	X	X	
Port Hastings Canal			Wind
Port Hood	X	X	
Pugwash	X	X	
River Denys	X	X	
River Hebert			Sunshine
River John	X	X	Wind, sunshine
Roseway	X	X	
Ruth Falls	X	X	
St. Margaret's Bay	X	X	
Salmon Hole	X	X	
Sandy Cove NRC	X	X	Wind, sunshine
Sheffield Mills	X	X	Nipher
Springfield	X	X	
Springhill	X	X	
Stillwater Sherbrooke	X	X	
Summerville	X	X	
Tusket	X	X	
Upper Stewiacke	X	X	
Waterville Cambridge	X	X	
Westphal	X	X	
Weymouth Falls	X	X	
White Rock	X	X	
Windsor Falmouth	X	X	Wind
Windsor Martock	X	X	Nipher
Wreck Cover Brook	X	X	Nipher

3.2 OPERATING AGREEMENT - SURFACE WATER NETWORK

Under the Memorandum of Agreement of April 1, 1975, between the governments of Canada and Nova Scotia, arrangements have been made for cost sharing and co-operation in the establishment, operation and maintenance of the stream gauging network.

Generally, Canada will construct, operate and maintain the stations in the network unless it is deemed and agreed to be more efficient for the Province to do this on a station by station basis. The cost of the network is shared according to the designation of each individual station. A Federal station is charged 100% to the Federal government, and similarly, a Provincial station is charged 100% to the Provincial government. A station designated as Federal-Provincial is cost shared on a 50-50 basis.

A station not funded by the Federal or Provincial Government is designated as "Other". This allows for cost recovery from other agencies who require the data but do not wish to or can not monitor the stream themselves.

It is the operating party's responsibility to provide staff to meet its commitments. It is the responsibility of the Federal government to ensure that the water quantity surveys are carried out to meet national standards, and that national guidelines are used for station designation, under the cost sharing formula.

The agreement cited in the "Water Quantity Surveys Federal-Provincial Cost Sharing Agreements - Annual Report" outlines the procedures to be used in computing the annual payments by each party, and the method by which the agreement may be revised or terminated.

The present network seen from the point of view of the cost sharing agreement is shown in Tables 3.11 and 3.12 and summarized in Table 3.13.

COST SHARING CLASSIFICATION OF NATIONAL AND REGIONAL INVENTORY HYDROMETRIC GAUGING STATIONS IN NOVA SCOTIA
SORTED BY HYDROLGIC ZONE AND DRAINAGE AREA SIZE

STATION NUMBER	D.A. (KM2)	YEARS	PERIOD	REGULATED FLOW	CLASSIFICATION FED	FED-PROV	STATION NAME
ZONE 2B							
01DD004	8.81	17	1967-83			3	SHARPE BROOK AT LLOYDS
01EJ004	13.1	4	1980-83			3	LITTLE SACKVILLE RIVER AT MIDDLE SACKVILLE
01EH003	26.9	58	1926-83			3	EAST RIVER AT ST. MARGARETS BAY
01DG003	96.9	62	1922-83			3	BEAVER RIVER NEAR KINSAC
01EJ001	146	14	1970-83			3	SACKVILLE RIVER AT BEDFORD
01DA001	167	20	1964-83	X		3	METEGHAN RIVER NEAR METEGHAN RIVER
01EG002	370	18	1966-83		4		GOLD RIVER AT MOSHER'S FALLS
01DG006	389	10	1974-83			3	SHUBENACADIE RIVER AT ENFIELD
01EC001	495	67	1916-83		4		ROSEWAY RIVER AT LOWER OHIO
01DC005	546	21	1963-83	X		3	ANNAPOLIS RIVER AT WILMOT
01EK001	650	68	1916-83	X	4		MUSQUODOBOIT RIVER AT CRANFORD FALLS
01EF001	1250	68	1916-83		4		LA HAVE RIVER AT WEST NORTHFIELD
01EE001	1390	69	1915-83	X		3	MEDWAY RIVER AT CHARLESTON
ZONE 2C							
01DH003	9.07	19	1965-83			3	FRASER BROOK NEAR ARCHIBALD
01FJ002	19.7	6	1978-83			3	MCASKILL BROOK NEAR BIRCH GROVE
01ER001	45.1	26	1957-83			3	CLAM HARBOUR RIVER NEAR BIRCHTOWN
01DP004	92.2	16	1966-83			3	MIDDLE RIVER AT ROCKLIN
01FH001	120	63	1921-83			3	GRAND RIVER AT LOCH LOMOND
01DR001	177	16	1917-33			3	SOUTH RIVER AT ST. ANDREWS
"	"	18	1966-83			3	" "
01FA001	193	18	1966-83			3	RIVER INHABITANTS AT GLENORA
01FJ001	199	18	1966-83			3	SALMON RIVER AT SALMON RIVER BRIDGE
01DH004	202	8	1976-83			3	NORTH RIVER AT NORTH RIVER
01DO001	249	18	1966-83		4		RIVER JOHN AT WELSFORD
01DH005	287	19	1965-83			3	SALMON RIVER AT UNION
01DN004	298	20	1964-83			3	WALLACE RIVER AT WENTWORTH CENTRE
01EN002	389	22	1962-83			3	LISCOMB RIVER AT LISCOMB MILLS
01EO001	1350	68	1916-83		4		ST. MARYS RIVER AT STILLWATER
ZONE 3							
01FB006	37.8	6	1978-83			3	LAKE O'LAW BROOK AT EGYPT ROAD
01FB003	357	65	1919-83			3	SOUTHWEST MARGAREE RIVER NEAR UPPER MARGAREE
01FB001	368	67	1917-83		4		NORTHEAST MARGAREE RIVER AT MARGAREE VALLEY

COST SHARING CLASSIFICATIONS

FED4 - FEDERAL 4: NATIONAL WATER QUANTITY INVENTORY
FED-PROV3 - FEDERAL-PROVINCIAL 3: REGIONAL WATER QUANTITY INVENTORY

TABLE 3.11

COST SHARING CLASSIFICATION OF PROJECT ORIENTATED HYDROMETRIC GAUGING STATIONS IN NOVA SCOTIA SORTED BY HYDROLOGIC ZONE AND DARAINAGE AREA SIZE

STATION NUMBER	D.A. (KM2)	YEARS	PERIOD	REGULATED FLOW	CLASSIFICATION PROV	FED	OTHER	STATION NAME
ZONE 2B								
01ED006	--	15	1969-83			1		KEJIMKUJIK LAKE
01DG041	2.58	1	1983-83				X	MUDDY POND BROOK AT WAVERLEY
01ED009	2.80	1	1983-83				X	ROGERS BROOK NEAR JAKES LANDING
01EE007	7.11	1	1983-83				X	WHITEBURN BROOK BELOW POLLOCK LAKE
01EJ005	15.1	2	1982-83	X		1		MCINTOSH RUN AT HERRING COVE ROAD
01EE005	16.7	3	1981-83			1		MOOSE PIT BROOK AT TUPPER LAKE
01DG017	26.7	1	1983-83				X	POWDER MILL LAKE BROOK NEAR WAVERLEY
01DG018	73.3	7	1977-83			1		PEMBROKE RIVER AT GLENBERVIE
01DG035	76.1	1	1974-74				X	SHUBENACADIE RIVER AT OUTLET LAKE WILLIAM
"	"	1	1983-83				X	" "
01DG007	106	1	1974-74				X	SHUBENACADIE RIVER AT LAKE THOMAS
"	"	1	1983-83				X	" "
01EE006	108	3	1981-83			1		ROUND LAKE BROOK AT ROUND LAKE
01EE004	198	3	1981-83			1		WESTFIELD RIVER NEAR NORTH BROOKFIELD
01ED007	295	15	1969-83			1		MERSEY RIVER BELOW MILL FALLS
01ED005	723	15	1969-83			1		MERSEY RIVER BELOW GEORGE LAKE
01DC007	1020	1	1983-83	X	2			ANNAPOLIS RIVER AT LAWRENCETOWN
01EA003	1070	53	1929-83	X		1		TUSKET RIVER AT WILSON'S BRIDGE
ZONE 2C								
01FJ003	23.3	1	1983-83				X	SOUTHWEST BROOK NEAR COLLEGE OF CAPE BRETON
01FA003	26.7	15	1969-83	X	1			NORTH LITTLE RIVER BELOW BEAVER DAM LAKE
01DL001	63.2	14	1970-83			1		KELLEY RIVER (MILL CREEK) AT EIGHT MILE FORD
01DR003	64.2	6	1978-83		1			RIGHTS RIVER NEAR ANTIGONISH
ZONE 3								
01FC003	37.0	6	1978-83	X	2			CHETICAMP RIVER BELOW ARTEMISE BROOK
01FC002	190	26	1958-83	X		1		CHETICAMP RIVER ABOVE ROBERT BROOK
01FE002	125	24	1960-83	X	2			INDIAN BROOK AT INDIAN BROOK

COST SHARING CLASSIFICATIONS

FED1 - FEDERAL 1: FEDERAL DEPARTMENTAL PROGRAMS
PROV1 - PROVINCIAL 1: PROVINCIAL DEPARTMENTAL PROGRAMS
PROV2 - PROVINCIAL 2: SPECIFIC PURPOSE MONITORING REQUIREMENTS
OTHER - OTHER REQUIREMENTS

TABLE 3.12

TABLE 3.13

FEDERAL/PROVINCIAL COST SHARING
CLASSIFICATIONS OF NATURAL AND REGUALTED STATIONS

Classification Type Description	Number of Stations Regulated	 Natural	 Total
Federal 1 - Federal Departmental Programs	3	8	11
Federal 4 - National Water Quantity Inventory	1	6	7
Federal-Provincial 3 - Regional Water Quantity Inventory	3	20	23
Provincial 1 - Provincial Department Programs	1	1	2
Provincial 2 - Special Purpose Monitoring	3	0	3
Other	0	7	7
Total	11	42	53

3.3 NETWORK STANDARDS

Network standards or guidelines have been established by various agencies in the world. In this section, the practices of the World Meteorological Organization (WMO) and the United States Geological Survey (USGS) are examined and compared to the current networks in Nova Scotia where applicable.

3.3.1 World Meteorological Organization Standards

The World Meteorological Organization (1974) has set established general principles for network design. However, the diversity of the terrain and of the water problems throughout the world makes it impractical to devise one universally satisfactory procedure for the design of hydrological and climatological networks.

WMO describes the optimum network as one which satisfies a very simple condition. This condition states that, by interpolation between values at different stations, it should be possible to determine, with sufficient accuracy for practical purposes, the characteristics of the basic hydrological and climatological elements anywhere in the country. These characteristics include all quantitative data, average and extremes, that define the statistical distribution of the element studied. Since economic as well as technical considerations must be considered in the design of the optimum network, it is suggested that the network be divided into three categories: (1) principal or base stations; (2) secondary stations; and (3) stations for specific purposes.

The above categories are defined as follows:

(1) Principal stations provide the basis for statistical studies and should be observed continuously and indefinitely. These stations should be located on water

courses with natural regimes as well as those with regimes modified by management activities.

(2) Secondary stations should be operated for a limited number of years only. These stations should function just long enough to establish a good correlation between them and the base stations, or with physiographic parameters.

(3) Special stations may be required for a specific purpose, or they may be established to augment the network of base and secondary stations. The length of operations of special stations is determined by the purpose for which they were installed, such as, research studies, or post development monitoring of power-related stream changes. These stations may be fully automated, or they may be manually read staff or crest gauges which are read only as required.

The WMO considers the following data to be of interest in the establishment of a minimum network. The emphasis placed on each of these types of data will vary, however, depending upon the problems likely to be encountered in water resource development. Some of the data types are listed below:

(a) Precipitation and snow cover
(b) Stage and discharge of rivers and stages of lakes and reservoirs.
(c) Evaporation and evapotranspiration
(d) Sediment transport and deposition
(e) Chemical quality of water
(f) Water temperature
(g) Ice cover on rivers, lakes and reservoirs
(h) Density of aquatic growth on river beds
(i) Soil moisture and groundwater levels

In establishing a hydrologic network, WMO has set minimum standards for each type of network.

(A) Three main physiographic regions are considered by WMO for determining the density of the precipitation gauge network. The minimum densities for precipitation stations for these categories are as follows:

Type of Region	Range of Norms for Minimum Network Area (km^2) per Station
1. Flat regions of temperate, mediterranean and tropical zones	600 - 900
2a. Mountainous regions of temperate, mediterranean and tropical zones	100 - 250
2b. Small mountainous islands (less than 20,000 km^2) with very irregular precipitation, very dense stream network	(less than) 25
3. Arid and polar zones	1500 - 10000

The Province of Nova Scotia would fall under category 2a. It has 88 climate stations over an area of 55,000 km^2 or 625 km^2 per station. At present, the minimum guideline of 100 to 250 km^2 per station is not met.

The precipitation gauging network should consist of standard (manual) recording and storage (for remote areas) gauges. Five to ten percent of this total should be of the recording type.

The location of the precipitation gauges relative to the stream gauging network is important to ensure that adequate data are available for extending streamflow records, for forecasting purposes or for water budget analysis. It is suggested that there should be at least two precipitation gauges for each stream gauge. One would be located at or near the stream gauge (depending upon the suitablility of the site), and the other located in the upper part of the drainage basin. In practical terms, this may be reduced in very small basins.

At present in Nova Scotia, there are 88 climate stations, nine (9) of which are principal (recording) stations. While the percentage of principal or recording stations is adequate, the total number of stations is less than the minimum recommended with a ratio of only 1.6 climate stations per hydrometric station, unfortunately few are in or near the gauged watersheds.

WMO recommends that snow surveys should be taken at precipitation stations where the winter snowmelt is not significant, that is, the snow remains for most of the winter. These data are useful for river forecasting and flood studies. It is suggested that one snow course be surveyed for each 1000 to 2000 km^2 in nonhomogeneous regions whereas one per 5000 km^2 in homogeneous plains areas is adequate.

In Nova Scotia, there are some areas which do not have significant snowmelt during the winter months. These would include the northern portions of Cape Breton Island and selected areas in the northern portion of the mainland, i.e. Cobequid Uplands and Pictou-Antigonish Highlands.

The 28 snow course stations which were sampled up until 1983 as shown in Appendix E-10 "Snow Course Sampling Sites" have been decreased to two sites (Greenwood and Truro) for the winter of 1984-85. The discontinued stations were sampled by Water Survey of Canada Division staff while the continuing sites are sampled by Atmospheric Environment Service. The reason for the discontinuance of this service was the lack of interest for the data and the priority placed on the field technicians' time.

(B) Stream Gauging Network Three main physiographic regions were considered for the determination of the density of the stream gauge network. The minimum densities for stream gauging stations for these categories are as follows:

	Type of Region	Range of Norms For Minimum Network Area (km^2) per Station
1.	Flat regions of temperate, mediterranean and tropical zones	1000 - 2500
2a.	Mountainous regions of temperate, mediterranean and tropical zones	300 - 1000
2b.	Small mountainous islands (less than 20,000 km^2) with very irregular precipitation, very dense stream network	140 - 300
3.	Arid and polar zones	5000 - 20000

The Province of Nova Scotia as a whole would fall under category 2a. It has 53 stations over an area of 55,000 km^2 or 1050 km^2 per station. At present, the minimum guideline of 300 to 1000 km^2 per station is not met. If the province is divided at the Strait of Canso, then Cape Breton Island (area 10,400 km^2) could be classed as 2b. With only twelve stations on the Island, the area per station is 867 km^2 which is significantly above the 140-300 km^2 per station range. However, if the Island were classed as 2a, which would be the same as the mainland, the density would be within the guidelines for a minimum network. Summing up, one could argue that the entire Province has a network density slightly less than that recommended by WMO for a minimum network.

In addition to the stage which is recorded at the stations, for the purpose of computing daily discharges, there are requirements for additional observations of water levels only. These requirements include:

(i) Sites at all major cities along rivers where river stages are used for flood forecasting.

(ii) On major rivers, at points between stream gauging stations, records of river stage may be used for flood routing and forecasting purposes.

There are few major cities in Nova Scotia, but numerous large towns which have flooding problems, many of which are due to ice jamming. Stage monitoring only exists at one location in Nova Scotia, namely Lake Kejimkujik located in the National Park of the same name. Crest gauges are simple devices, which can record the high water level or crest of a flood event by leaving a mark at the high water level provided that it occurs within the range of the gauge. Crest gauge monitoring has only been done on a project basis by consultants conducting studies under Flood Damage Reduction Program contracts.

(C) Evaporation Network The WMO does not suggest a method for measuring evaporation, but outlines the problems encountered with using evaporation pans. It suggests that if pans are used then other data should be collected. These data may be used in reliable computational formulae to estimate the evaporation or evapotranspiration. These data include net radiation, air temperature, humidity, wind and surface water temperatures.

In Nova Scotia, three evaporation measurement sites exist as shown in Appendix E-11 "Active (1983) Evaporation Measurement Stations". The principal station at Truro and the secondary stations at Kentville CDA and Nappan CDA are the only climate stations measuring pan evaporation. Research presently underway by Morton et al (1984) is estimating actual evaporation and transpiration from routinely published records of temperature, humidity and sunshine duration. It is feasible that these stations could be replaced or complemented by climate stations with instrumentation to provide the required data for the technique.

(D) Sediment Transport and Deposition The sediment network may be designed to measure the total sediment discharge to the ocean, or to measure the erosion, transportation and deposition of sediment within the country, the latter being emphasized in the design of the minimum network. Since streamflow is essential to the measurement of sediment transport, the suspended sediment stations should be co-located with the hydrometric stations. WMO (1974) recommends that sediment transport be measured at 15% of the hydrometric stations .

In Nova Scotia there are four active sediment stations, representing 7% of the present hydrometric network stations.

(E) Chemical Quality of Water It is suggested that water quality sampling be conducted at hydrometric stations where it may be used to determine the usefulness of a supply of water in terms of its chemical quality. The number of observation sites required depends on the variability of the water quality and should increase with an increase in chemical concentrations. Accordingly WMO (1974), the minimum water quality network is 5% of the hydrometric stations.

In Nova Scotia, 16 stations or 28% are monitored for water quality.

(F) Water Temperature The temperature of water in flowing streams should be measured and recorded during each station visit. These data are useful in studies of aquatic life, pollution, ice formation, sources of cooling water for industry, temperature effects in sediment transport and solubility of mineral constituents.

In Nova Scotia, continuous temperature data are collected at four stations:

01ED006	Kejimkujik Lake
01ED005	Mersey River below Lake George
01FB003	Southwest Margaree River near Upper Margaree
01DG018	Pembroke River at Glenbervie

At all other stations, the temperature is recorded during each visit to the station.

(G) Ice Cover on Rivers and Lakes Regular observation of ice cover should include:

(a) Visual observations of various processes of ice formation and destruction on a daily basis from the formation of frazil to the date at which the ice has completely vanished.

(b) The simultaneous measurement of ice thickness at two or three selected points near each hydrometric station should be made every five to ten days.

In Nova Scotia, ice thickness and characteristics are only noted and measured at the gauge measurement site during the monthly station visit.

(H) Density of Aquatic Growth in River Beds Vegetation in river beds retards the flow and therefore affects the stage-discharge relationship. Notes should be made on the types of plants and their stage of growth.

In Nova Scotia, weed growth is normally noted only when it affects stage in the river near the control for the hydrometric station.

(I) Soil Moisture and Groundwater Level Observations of soil moisture and groundwater level provide important hydrologic data, useful in water balance studies and analyses.

In Nova Scotia, soil moisture data are not collected on a network basis. While some groundwater monitoring wells coincide with hydrometric stations, this co-ordination has not been designed into the respective networks.

3.3.2 United States Geological Survey Approach

The United States Geological Survey (USGS) is responsible for the measurement of streamflow, groundwater levels and water quality in the United States. Its networks have grown slowly but steadily through the years as Federal and State interests in water resources have increased and as more funds for operating the stream gauging network have become available.

Many of these networks have evolved to meet management or legal requirements, as water law in many states follows the Riparian Rights doctrine. With increasing costs of operation, the restraint on funds and manpower, and the need for a greater variety of hydrologic information, it became imperative that a systematic evaluation of the streamflow gauging program be made in order to determine the most cost effective means of providing various types of information.

The USGS undertook a national study of the stream gauging program in 1970 (Benson and Carter, 1973). The objectives of the study were:

1) establishing the objectives and goals of the program;
2) analyzing all available data to determine which of the goals have already been met;
3) considering alternate means of meeting the remaining goals; and,
4) identifying the elements which should be included in the future program.

The objectives of the streamflow data program were to provide information on flow characteristics at any point on any stream.

The general principle of the streamflow program is that in the United States streamflow information may be needed at any point on any stream and that the program must be designed to accommodate this need.

The streamflow data are divided into four types:

(i) data for current use
(ii) data for planning and design

(iii) data to define long term trends
(iv) data on the stream environment.

The planning and design data are further subdivided into natural and regulated flow, and these are again subdivided into principal streams and secondary streams. Goals are established for the operating approach and accuracy required for each type. Once these criteria are established, the present data are examined and analysed. These data are compared with the goals as set, and consideration is then given to the basic hydrologic and meteorologic elements that need be included in the future program.

Through the use of multiple regression analysis relating the streamflow to the topographic and climatic characteristics that affect streamflow, and flow characteristics of natural streams, it should be possible to determine the flow characteristics of ungauged sites with a predetermined degree of accuracy. Where flows are regulated, analytical modelling of the system may be required.

The USGS undertook another nation-wide evaluation of the stream gauging program in 1983 (Fontaine et al, 1984). The objectives were:

(1) To evaluate the program with respect to the needs of the data users and the utility of the data.
(2) To investigate the cost effectiveness, accuracy and information content of alternative methods of providing streamflow information such as flow routing and statistical methods.
(3) To utilize techniques in Kalman filtering and mathematical programming to define strategies for operating the stream-gauging program to minimize the uncertainty in the streamflow records.

The USGS has now taken the approach of testing the data from various stations to determine whether the data can be estimated to a predetermined accuracy criterion through alternate methods to stream gauging such as flow routing or multiple regression methods. Once this has been complete, an economic analysis is performed on the network to determine the cost-effective methods of operating the network. This analysis relates the standard error of the instantaneous discharge to the operating budget for the stream gauging program. The major component of the standard error is contributed during periods of missing records. By optimizing the field requirements to minimize the cost of data collection relative to an acceptable standard error level, efficiencies can be effected in the network resulting in savings in budget.

3.3.3 Other Comparative Methods

Comparative analyses were performed, for this review, on the various hydrometric and climate networks in the Canadian provinces and territories by Water Resources Branch. These were similar to those performed by Langbein (1960). Figures 3.1 and 3.2 show the relative densities of the various networks. It can be noted from Figures 3.1 and 3.2 that the Nova Scotia networks are of a higher density than other provinces. This shows that some requirement has been noted either directly or indirectly for a more dense network as is also recommended by WMO (1974). It may also be noted that in relative terms between the hydrometric and precipitation statics, Nova Scotia's hydrometric station density is lower than the precipitation station density. This trend is noted only in Prince Edward Island, Newfoundland and Nova Scotia, which are all virtually surrounded by water.

This shows the need for a greater precipitation station density in the Maritime environment.

FIGURE 3.1

COMPARATIVE DENSITIES OF STREAMFLOW GAUGE NETWORKS OF CANADA

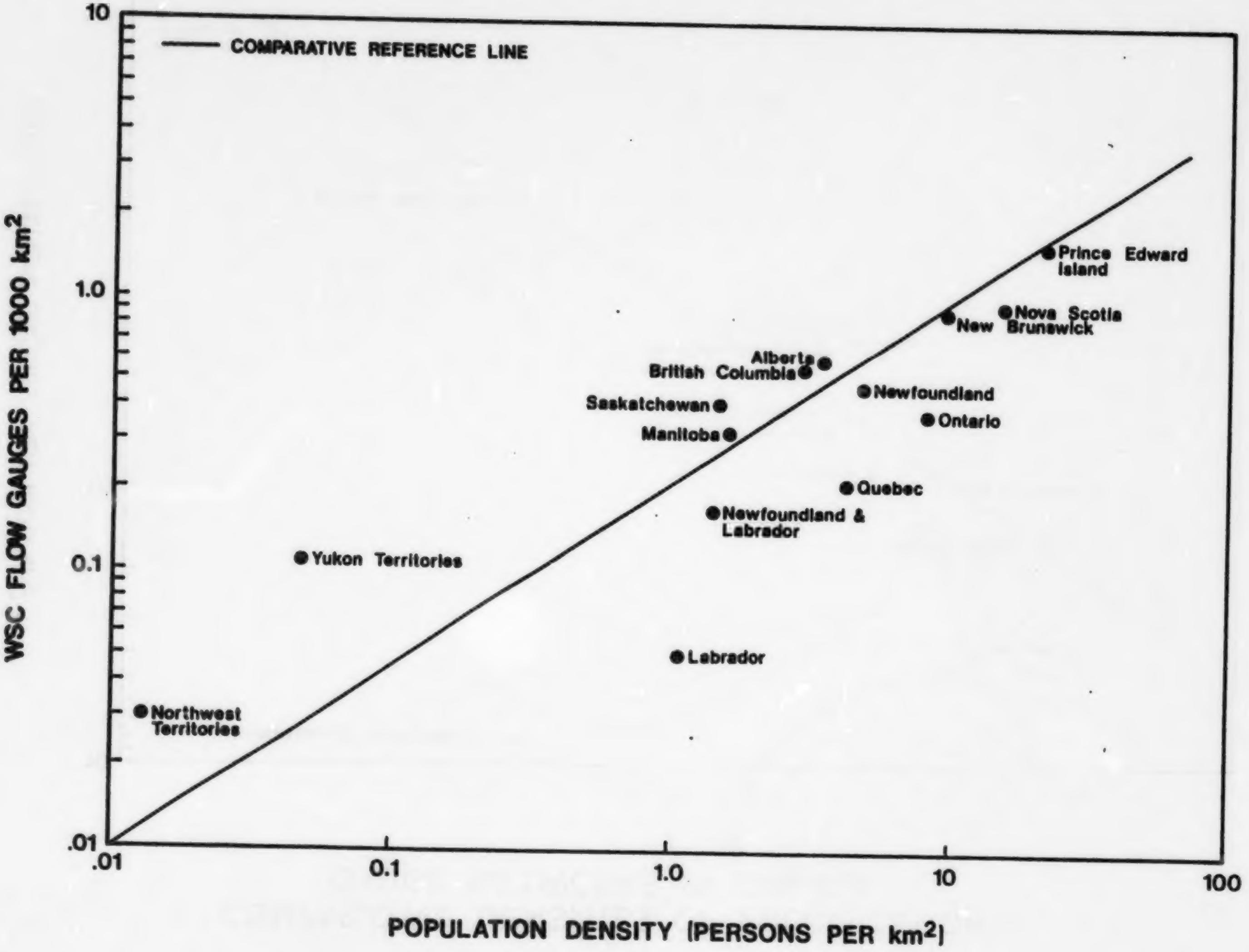
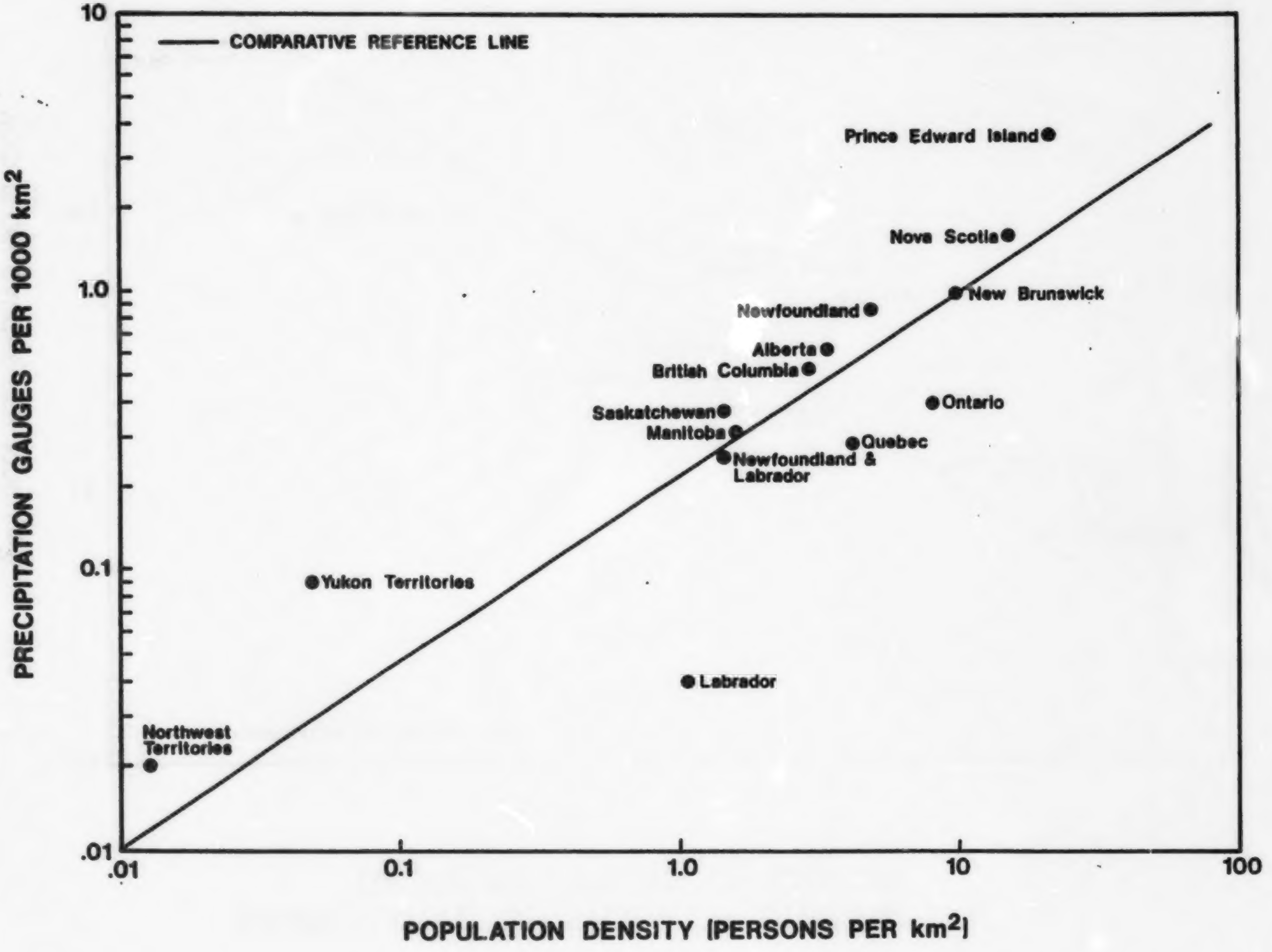


FIGURE 3.2

COMPARATIVE DENSITIES OF PRECIPITATION GAUGE NETWORKS IN CANADA



CHAPTER 4

REVIEWS OF EXISTING NETWORKS

Hydrometric surveys began in Nova Scotia about 1916. By the end of 1966, there were thirty-five recording gauges and one manual gauge maintained in Nova Scotia. Until that time, stream gauging stations were mainly installed as a result of some existing or pressing need for information at a specific location. This practice generally led to an unbalanced coverage of the area. Influenced by work published by authors such as Langbein (1960) on networks during the late 1950's, work began on the assessment and planning of the hydrometric network in Nova Scotia.

This chapter looks at the objectives and the findings of some past network reviews.

4.1 OBJECTIVES OF PAST NETWORK REVIEWS

Three reviews of the hydrometric network have been recorded since the establishment of the network. In 1967, the in-house assessment was performed basically to summarize the existing network in terms of the hydrologic regions of Nova Scotia, to identify deficiencies in the network, and to suggest additional sites that should be considered to complete the basic network.

The next network review was completed in 1970 by T. Ingledow and Associates. This was a comprehensive review of the entire Atlantic Region with the objective of establishing a network of hydrometric stations which would provide uniform and adequate coverage of the region. The objectives of this report were to outline a network that would progressively provide the data that are needed for management of the water resources of the Region, as well as for increasingly sophisticated approaches that are being developed for the estimation of data at ungauged sites.

The third review released in 1984 was designed to look at the network from the point of view of the spatial distribution of the network stations in terms of the size of the drainage areas monitored. From these analyses it was possible to determine gaps or redundancies in the network under this drainage area criteria.

4.2 STATISTICAL FINDINGS

The Ingledow report noted that the division of the region into hydrologic zones was a complex problem which could not be resolved by any unique mathematical technique involving a single runoff parameter. Through statistical analysis of the mean flow, coefficient of variation, flow dependability and floods, several hydrologic zones were delineated.

The zones that were distinguished in Nova Scotia, which were all classified as part of the Marine Region, are as follows (See Appendix E-3), "Hydrologic Zones and Major Rivers of Nova Scotia".

2B - Southwestern Nova Scotia
2C - Northeastern Nova Scotia, excluding Cape Breton Highlands
3 - Cape Breton Highlands.

The main division in the Marine Region is between the Cape Breton Highlands, with its generally high elevations, high annual precipitation and runoff and a unique distribution of runoff, and the rest of the Province. A secondary zone division appears to exist through the centre of the Province, roughly just above 45° Latitude. This secondary zone appears to be required for flood flow and flood studies. The delineation of the zones, as shown in Appendix E-3 "Hydrologic Zones and Major Rivers of Nova Scotia", are only estimates based on the data available. The lines have been drawn to follow the basin divides with the exception of the Shubenacadie River, which is divided near the outlet of Grand Lake.

In analysing the coefficient of variation (C_v), various correlations were attempted against various parameters, but results were not satisfactory. Ingledow (1970) found that the best results for a relationship between C_v and the basin locations, were obtained by using the location of the centroid of the catchment basins relative to a reference baseline drawn between Yarmouth and Sydney. The relationship of the line to the network was not given but one may speculate that with the exception of the isthmus, where there was little data to influence the relationship, the line acts as a baseline equidistant from the ocean which is a major influence on the regional hydrology.

From this correlation, it was suggested that the hydrologic zones 2A (New Brunswick Fundy Shore), 2B, 2C and 3, all of which have a marine climate, can be combined into a single statistical unit with regard to the coefficient of variation.

Through analyses of dependable flow curves, it was once again demonstrated that the Cape Breton Highlands were distinct from the rest of the Province.

Analysis of the flood flows showed the delineation of the zones to lie along the aforementioned zones 2B and 2C. Although station 01EK001, Musquodoboit River at Crawford Falls showed a better fit within the northeast zone (2C), it was kept in the southwest zone (2B). Consequently for all purposes, the Province should be divided into the three zones outlined in Appendix E-3 "Hydrologic Zones and Major Rivers of Nova Scotia".

Ideally if the province can be divided into homogeneous zones, regional regression analyses could provide families of regression equations for each zone. These equations would be more accurate than similar equations over the entire province and produce better information on ungauged streams.

4.3 NON-STATISTICAL FINDINGS

Networks are often assessed in terms of their geographic, geologic, physiographic and climatic characteristics. Networks are also compared with others in the world, especially between the developed and developing countries through organizations such as the World Meteorological Organization (WMO) and the United Nations.

The 1967 network assessment was conducted when the network consisted of 36 active hydrometric stations. This report found that there were areas deficient in coverage.

The 1984 analysis of the network was performed on the network in terms of the spatial distribution of various drainage area sizes. This assessment was made on a network that, in 1982, had 51 active hydrometric stations. Results show that with the exception of one station (Kelly River), the same areas that were deficient in 1967 are still deficient.

The present stream gauge density is 0.9 stations per 1000 square kilometres. According to the WMO criteria as outlined in section 3.3.1, the stream gauging density should be in the range of one (1) station in 300 to 1000 square kilometre, or 3.3 to 1.0 stations per 1000 square kilometres which puts the network below the minimum density recommended by WMO (1974). Similarly, the precipitation gauge network can be compared. The present precipitation gauge network density is 1.6 stations per 1000 square kilometres. The WMO criteria set the minimum density at 4 to 10 stations per 1000 kilometres. Here again the network appears sparse.

4.4 RECOMMENDATIONS FROM PREVIOUS REVIEWS

4.4.1 1967 Report

The 1967 report was the first recorded attempt at a network review and its findings were not surprising. The report concluded that the hydrometric gauge network was deficient in the following areas of the Province:

1. Areas draining the northern and southern shores of the Minas Basin.
2. Areas adjoining the Northumberland Strait, especially near the Nova Scotia-New Brunswick border.
3. The southern tip of the Province.
4. The eastern shore from Halifax to Liscomb.
5. The vicinities of Canso and Sydney.

In an attempt to balance the network by regions, watersheds in unrepresented areas were delineated and information on the proposed sites examined. A selection process was started and the most feasible sites selected.

The report recommended the establishment of 11 new stations to meet the primary coverage requirements for the Province. These stations are listed in Table 4.1

None of these exact stations was established, however, a station was established in the sub-basin adjacent to Apple River, namely Kelley River (Mill Creek) at Eight Mile Ford (01DL001) in 1969. Each recommended site was considered but was dropped after further office scrutiny or field reconnaissance which showed the lack of a suitable location for a stream gauge. Sites are considered suitable if they possess good hydraulic characteristics (i.e., stable control, minimal backwater effect and good velocity metering sites), and are operationally feasible to observe and maintain.

TABLE 4.1

ADDITIONAL STATIONS RECOMMENDED IN THE 1967 HYDROMETRIC NETWORK REPORT

Proposed Station Name	Sub-basin Index Number	Drainage Area (sq. mi.)
1. Apple River at East Apple River	1DK	30.5
2. Evans Brook near Round Hill	1DC	72.7
3. Great Village River at Great Village	1DJ	38.0
4. Kennetcook River near Kennetcook	1DF	64.7
5. Larry's River near Larry's River	1EQ	21.5
6. Salmon River near West Roachvale	1EQ	89.7
7. Sherbrooke River near Forties Settlement	1EF	48.0
8. Shinimikas River at Shinimicas Bridge	1DM	51.5
9. Silver River near North Kemptville	1EA	98.5
10. Stewiacke River near Upper Stewiacke	1DG	162.0
11. Tangier River near Tangier	1EL	112.5

4.4.2 Ingledow Report, 1970

The recommendations which pertained to the Nova Scotia network are related to the streamflow and sediment networks.

(A) Streamflow Network Plan A minimum of 5 additional streamflow stations were recommended to complete the regional network plan. It was felt that these stations were required to ensure the evolution of an adequate inventory of the surface water resources of Nova Scotia. Many of the recommended areas were similar to those in the 1967 in-house report. These include:

East Apple River
Great Village River
East River Sheet Harbour or Tangier River
Bear River
Kennetcook River

The authors felt that their report was a phase of what must be a continuing program of hydrometric network planning and development if necessary information is to be provided to ensure optimum utilization and successful development of the water resources of the Atlantic Region. Special recommendations for additional studies are listed below:

1. There is a definite requirement for a thorough appraisal of the historical records of existing hydrometric stations:
   (a) To classify the purpose of each station and to determine which stations are suitable for inclusion in the network.
   (b) To assess the need for, and advisability of reconstructing the records of flows which have been modified by diversions and storages.
   (c) To assess the accuracy of historical data and recommend steps to be taken to upgrade such data.
   A program of data adjustment based on the findings of (b) and (c) should then be considered.

2. A systematic plan should be developed and implemented for a secondary hydrometric network which will provide information in addition to the base network. The additional stations envisaged are peak flow, low flow, and short term continuous recording stations which would collect the additional data needed for defining regional streamflow characteristics to required degrees of accuracy.
3. It is recommended that the trend of closer co-ordination of hydrometric and meteorologic planning be continued.
4. It is recommended that a continuing series of short and relatively inexpensive studies be carried out to assess and develop promising computational techniques for estimating streamflow data from the data collected from the regional network. Criteria or guidelines for accuracy standards in the collection of hydrometric data based on an analysis of benefit-cost relationships as discussed in the report, should be set.
5. It is recommended that work on the preparation of a set of regional hydrology manuals be commenced at the earliest opportunity based on presently available information, with the object of publication for use by all data users, public and private. It is considered that this work could best be undertaken by the Water Survey of Canada, consultants and water resources departments of the universities, working jointly as recommended by the Science Council of Canada in their special Study No. 3, entitled "Major Program of Water Resources Research in Canada".

(B) Sediment Network Plan Based on a preliminary investigation of the erosion-sedimentation characteristics, 5 additional sediment measuring stations were recommended to provide a basic regional network for sediment data collection in Nova Scotia. It was felt that these stations were required to reference or monitor the erosion and sediment transport rates, and for the development of adequate means to estimate sediment yields under existing and modified land usage. The proposed sediment stations would be located at, and should be operated in conjunction with, existing or proposed streamflow stations.

It is further recommended that:

1. Special emphasis be placed on the development of relationships between land use and sediment yield, particularly in connection with logging activities. Such studies would normally be carried out as research projects on small pilot watersheds.
2. When sufficient sediment data are available from the base network stations, studies involving multiple regression techniques should be considered to correlate sediment yield and watershed physiographic and hydrometric parameters. At that stage, it may be worthwhile considering the installation of secondary sediment stations located in selected sediment zones, possibly on a temporary basis, to establish station density-accuracy criteria.
3. It is recommended that increased attention and support be given to research and development of sediment instruments and measurement techniques as discussed above for streamflow.

4.4.3 Drainage Area Analyses, 1984

In the report "Analysis of Active Hydrometric Networks Based on Drainage Area" Brimley (1984) the spatial distribution of hydrometric gauging stations by the size of the drainage area monitored was analyzed. The report identified 10 pairs or groups of stations, totalling 27, which monitored similarly sized drainage areas within close proximity, and recommended that these be reviewed under other priorities to identify redundancies. The list of stations is reproduced in Table 3.1. The report also identified areas that showed a deficiency of stations monitoring a specific category size of drainage area. The categories were based on the logarithm of the drainage areas as follows:

Drainage Area Category	Drainage Area Range (km^2)
1	0 - 10
2	10 - 100
3	100 - 1,000
4	1,000 - 10,000
5	10,000 - 100,000

Under these categories, the following areas were noted as deficient:

(a) Categories 1 and 2 are required in the area comprised of Digby, Yarmouth and Shelburne Counties.

(b) Category 3 is required in an area located around St. Margaret's Bay and stretching north to the Minas Basin and on to the Northumberland shore, west of Tatamagouche and an area comprised of the eastern portions of Antigonish and Guysborough Counties.

(c) Category 4 is required in areas including the central portion of the Province from Northumberland Strait to the Atlantic Coast, and the Highlands of Cape Breton in the western part of the island.

These areas again overlap the recommendations of the previous two reports.

ACTIVE DISCHARGE HYDROMETRIC GAUGING STATIONS IN NOVA SCOTIA
WITH SIMILAR DRAINAGE SIZE AND LOCATION

STATION NUMBER	DRAINAGE AREA	LAT.	LONG.	FLOW		STATION NAME
				NAT	REG	
01EJ004	13.1	444549	0634120	X		LITTLE SACKVILLE RIVER AT MIDDLE SACKVILLE
01EJ005	15.1	443631	0633701		X	MCINTOSH RUN AT HERRING COVE ROAD
01FJ002	19.7	460659	0600026	X		MCASKILL BROOK NEAR BIRCH GROVE
01FJ003	23.3	461020	0600533	X		SOUTHWEST BROOK NEAR COLLEGE OF CAPE BRETON
01FC003	37.0	463702	0604403		X	CHETICAMP RIVER BELOW ARTEMISE BROOK
01FB006	37.8	461853	0605823	X		LAKE O'LAW BROOK AT EGYPT ROAD
01DG018	73.3	451554	0625629	X		PEMBROKE RIVER AT GLENBERVIE
01DG035	76.1	444706	0633503	X		SHUBENACADIE RIVER AT OUTLET LAKE WILLIAM
01DP004	92.2	452950	0624651	X		MIDDLE RIVER AT ROCKLIN
01DG003	96.9	445106	0633954	X		BEAVER RIVER NEAR KINSAC
01DG007	106	444905	0633649	X		SHUBENACADIE RIVER AT LAKE THOMAS
01DH004	202	452530	0631520	X		NORTH RIVER AT NORTH RIVER
01DO001	249	454342	0630309	X		RIVER JOHN AT WELSFORD
01DH005	287	452354	0630723	X		SALMON RIVER AT UNION
01DN004	298	454042	0633335	X		WALLACE RIVER AT WENTWORTH CENTRE
01FB003	357	461324	0610812	X		SOUTHWEST MARGAREE RIVER NEAR UPPER MARGAREE
01FB001	368	462210	0605836	X		NORTHEAST MARGAREE RIVER AT MARGAREE VALLEY
01EN002	389	450054	0620545	X		LISCOMB RIVER AT LISCOMB MILLS
01EK001	650	445218	0631318		X	MUSQUODOBOIT RIVER AT CRAWFORD FALLS
01EC001	495	435018	0652212	X		ROSEWAY RIVER AT LOWER OHIO
01ED005	723	442000	0651216	X		MERSEY RIVER BELOW GEORGE LAKE
01EF001	1250	442648	0643530	X		LA HAVE RIVER AT WEST NORTHFIELD
01EE001	1390	441024	0643936		X	MEDWAY RIVER AT CHARLESTON

TABLE 4.2

CHAPTER 5

USERS SURVEY

5.1 INTRODUCTION:

A questionnaire, presented in Appendix A, was prepared and sent to a broad coverage of known and potential users of hydrologic data. A total of 151 users were contacted. These users included, A) private industries such as mining, pulp and paper and forestry, consulting engineers and hydrologists, wildlife interests, utilities, and universities; B) civic and municipal government agencies; and C) federal and provincial government agencies.

The users survey was intended to provide answers for the following:

1) Who uses this information?
2) What is their use of the data?
3) What presentation of the data is best suited for their application?
4) Within what time frame is the data required? (i.e.: real time, one month, one year)
5) Is the present Network coverage sufficient or is more required and if so where?
6) What is their dependency on this type of data?
7) What is the dollar value of their programs or operations to which this hydrologic information has contributed?

5.2 RESULTS OF USERS SURVEY

Questionnaires were sent to 151 known and potential users. A total of 109 or 72% of these replied, 38 of whom were not concerned with the data, and 71 answered in detail.

Question #1 was used to determine what network coverage would be desirable in the Province. The results indicate that complete provincial coverage would be desired.

The replies to questions #2 to #10 inclusive, are presented in bar graph form on the following pages. The bars in the graphs indicate the percentage of possible response (71 = 100%), with the number at the top of each bar being the actual number responding. The format indicated in the example is repeated in each graphed response. Question #4 was used to determine types of work being done by the users and resulted in a reiteration of question #3.

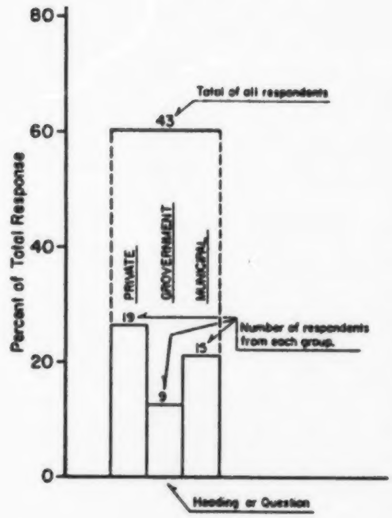
Question #11 asked for a dollar value to be assigned to programs to which these types of hydrologic information have contributed. This question was answered on the basis of $/annum with the following results.

Type of User	Value ($1,000/yr)	Response Ratio*	Response (%)
A Private Concerns	$123,490	14/26	54%
B Civic and Municipal Governments	2,675	11/30	44%
C Federal and Provincial Governments	551,650**	6/15	40%
TOTAL	$677,815	31/71	44%

*Number Responding/Total Respondents

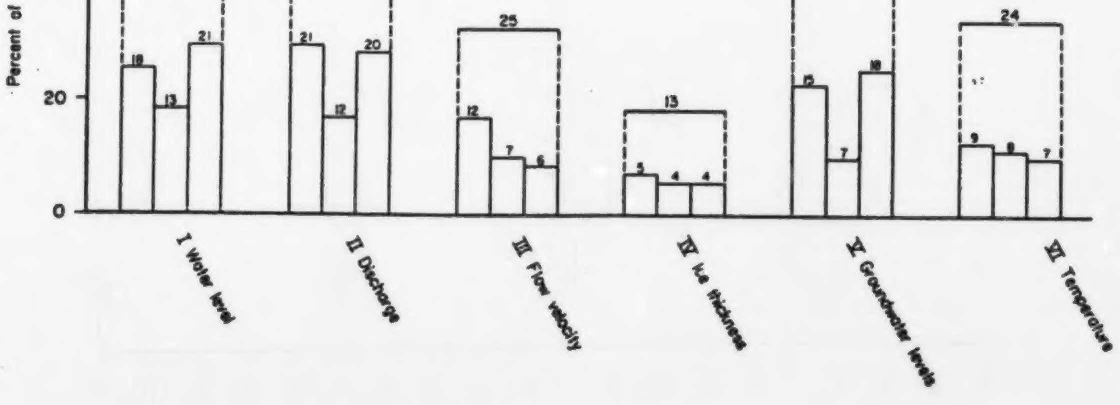
**Approximately $550,000,000 of this is used for hydroelectric power generation.

Questions #12,13 and 14 were intended to be used as indicators

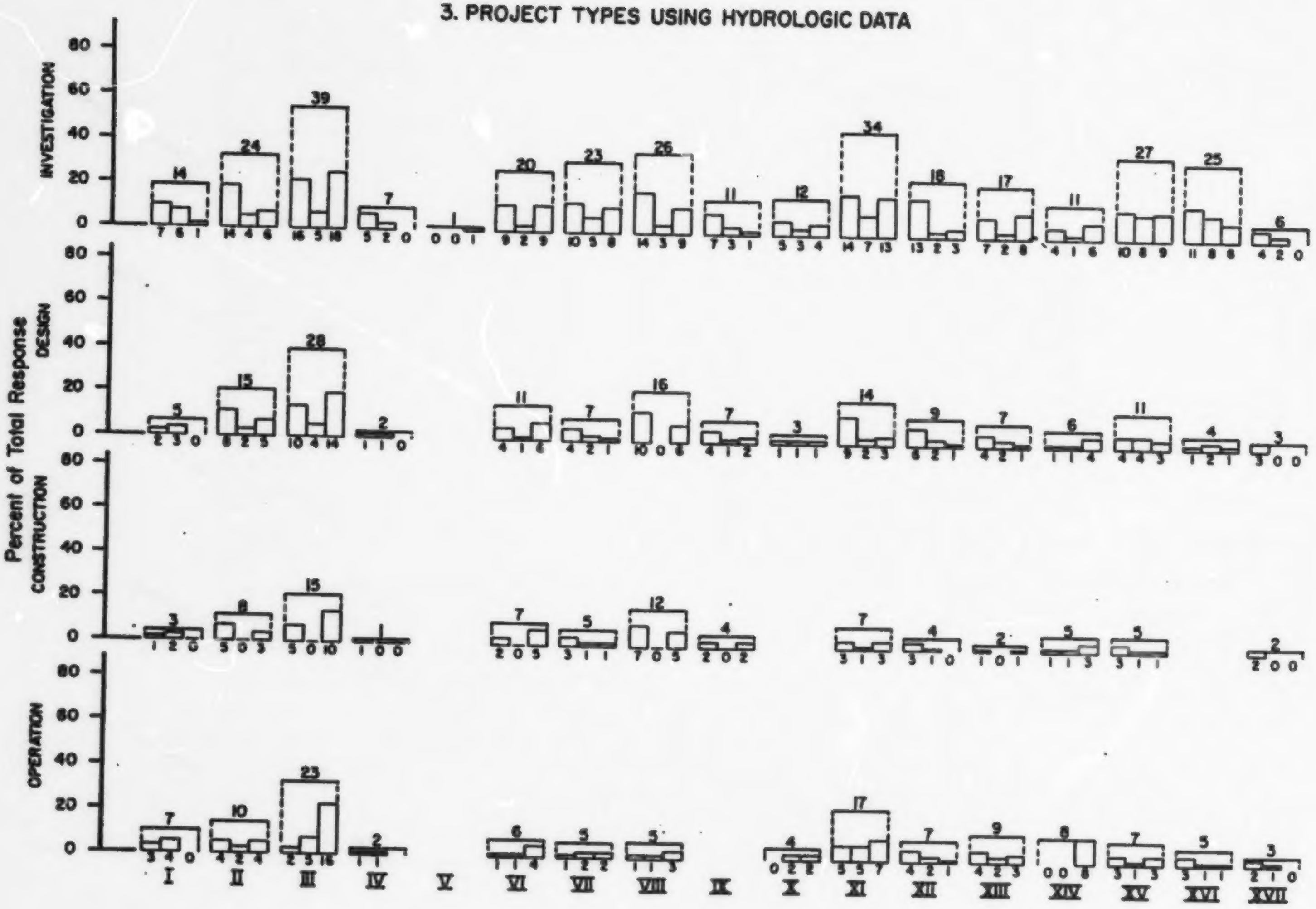


EXAMPLE

2. TYPE OF DATA REQUIRED



3. PROJECT TYPES USING HYDROLOGIC DATA



I. - Hydroelectric power

II. - Withdrawals for industrial use

III. - Withdrawals for municipal and residential use

IV. - Withdrawals for irrigation use

V. - Navigation

VI. - Flood mitigation using storage

VII. - Flood forecasting

VIII. - Storm-water drainage

IX. - Bridge design

X. - Low-flow augmentation

XI. - Water quality assessment

XII. - Monitoring effects of waste disposal

XIII. - Water management and apportionment

XIV. - Recreation

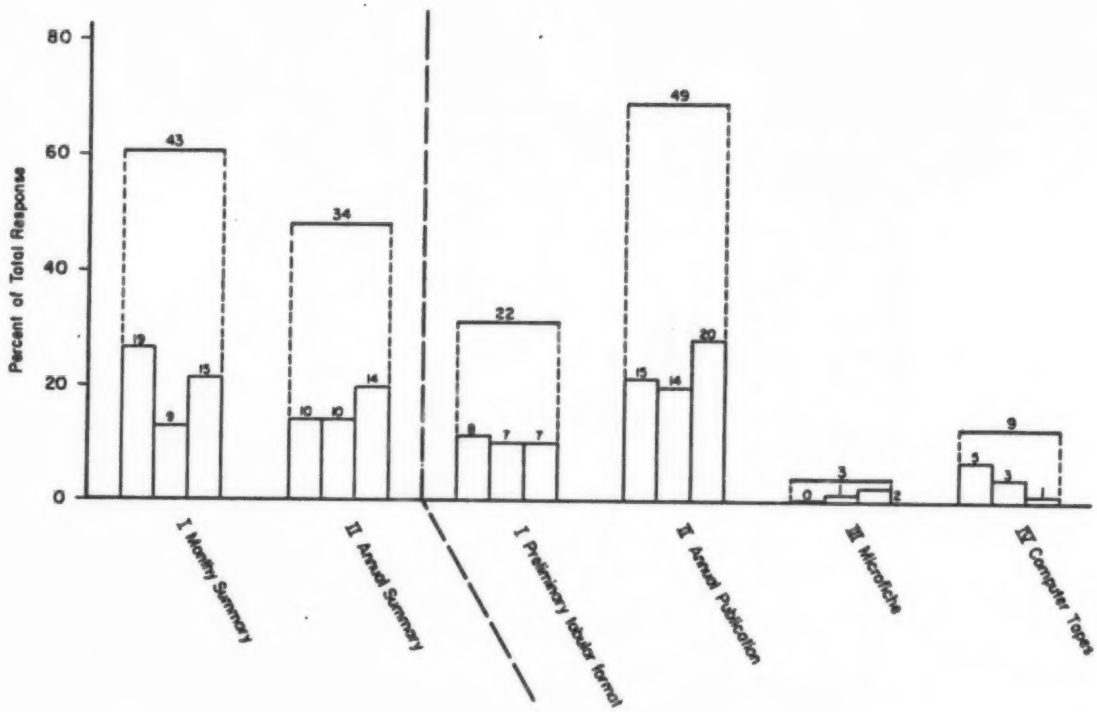
XV. - Planning and resource evaluation

XVI. - Investigation and/or research

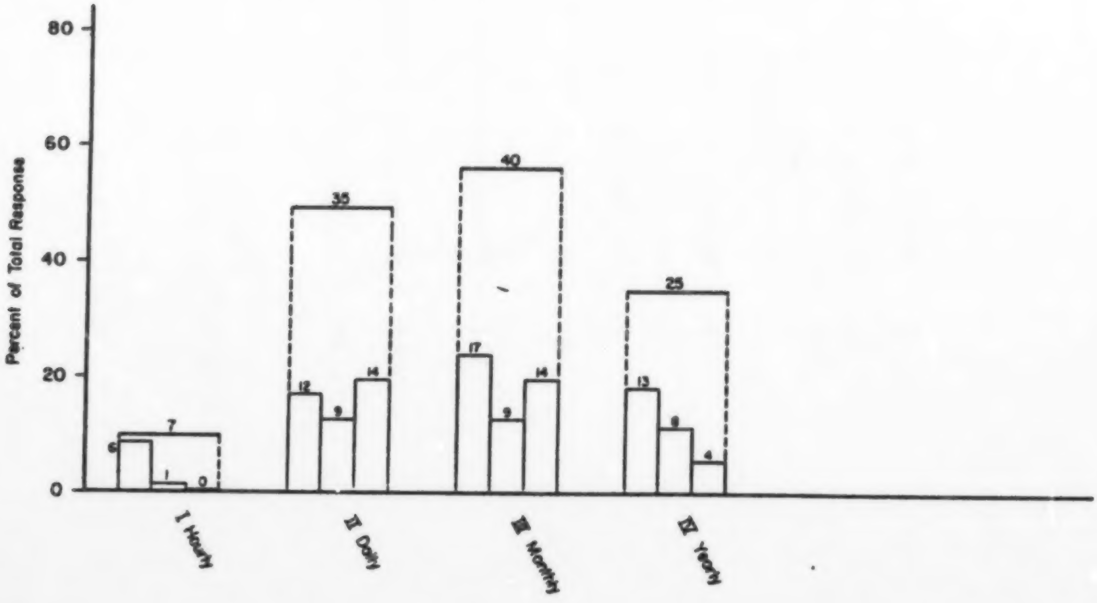
XVII. - Other

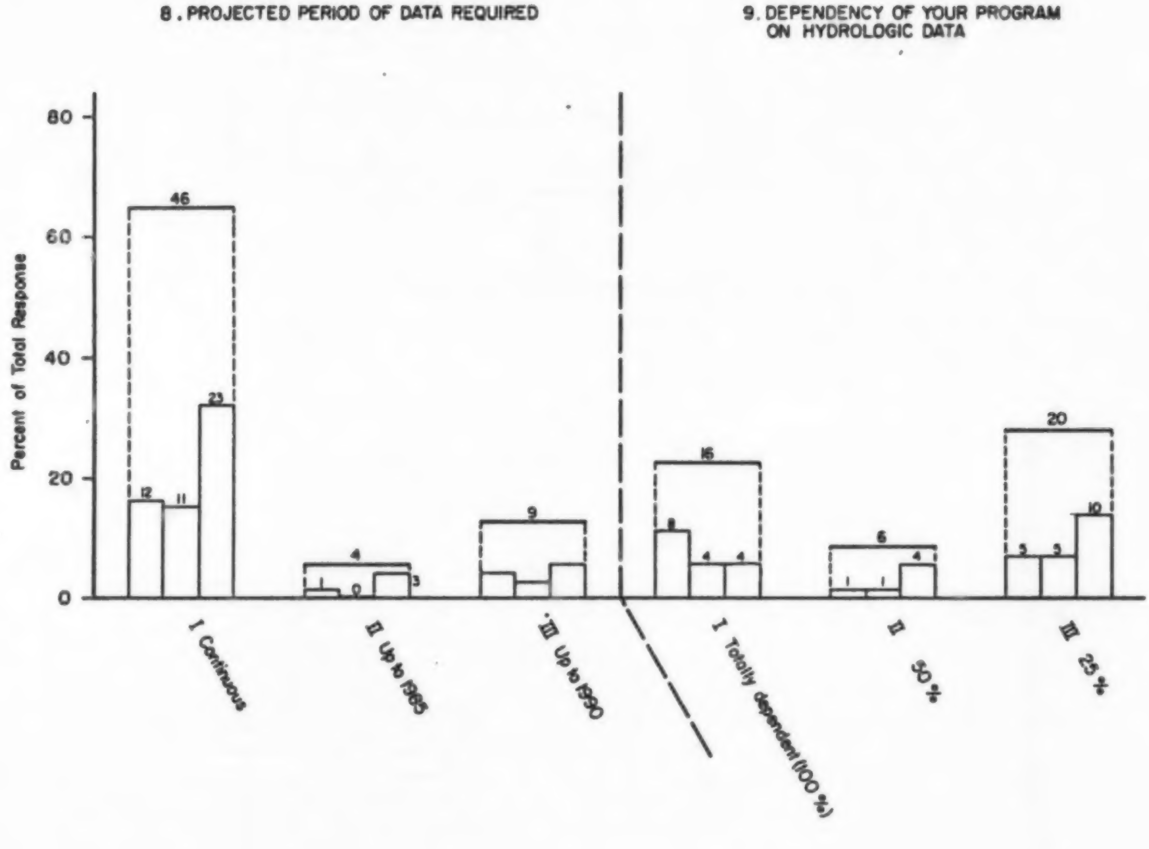
5. TIME PERIOD COVERAGE

6. FORMAT OF DATA REQUIRED

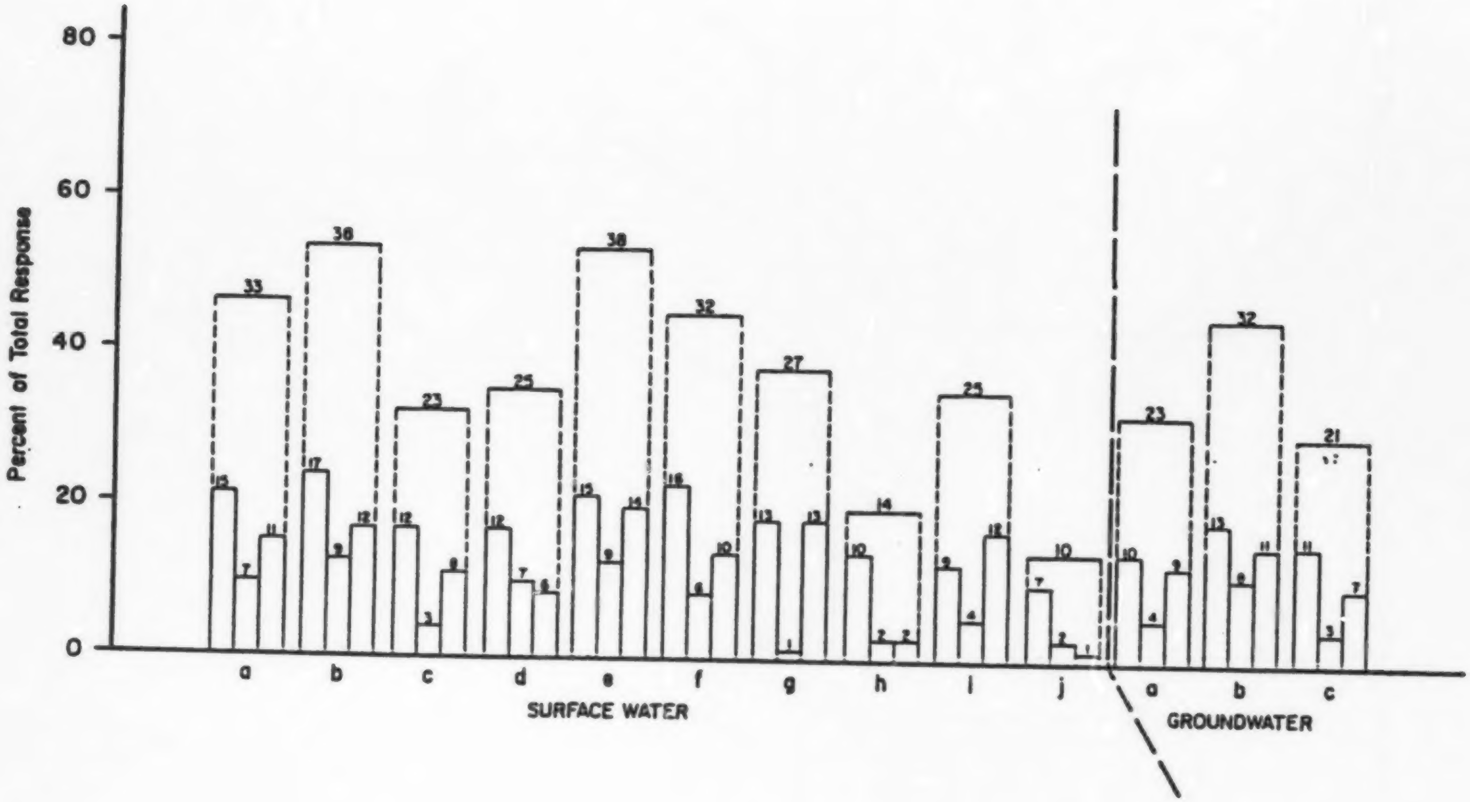


7. FREQUENCY OF DATA REQUIRED




8. PROJECTED PERIOD OF DATA REQUIRED
9. DEPENDENCY OF YOUR PROGRAM ON HYDROLOGIC DATA
Percent of Total Response
80
60
40
20
0
46
12
11
23
4
1
0
3
9
16
8
4
4
6
1
1
4
20
5
5
10
I Continuous
II Up to 1985
III Up to 1990
I Totally dependent (100 %)
II 50 %
III 25 %

10. TYPES OF ANALYSES REQUESTED



Surface Water:

(a) Annual Mean, Sd and Cv
(b) Monthly Mean, Sd and Cv
(c) Daily Mean & Population Skew. vs. statistics of extremes
(d) Duration analysis, flow vs. percent time exceeded daily
(e) Low flow frequency
(f) High flow frequency
(g) High flow vs. drainage area (observed and frequency analysis)
(h) Correlation of Paired Stations (daily, monthly)
(i) Dependable flows
(j) "Paired" station comparisons

Groundwater

(a) Mean Annual water level, Sd and Cv
(b) Mean Monthly water level, Sd and Cv
(c) Present available physical data (lithologies, pump tests, and transmissivities).

for background data to use in this report and provision for individual's comments. These were generally left unanswered and as a result will not be included in this summary.

5.3 SURVEY SUMMARY

The survey results indicate that the types of data most required are surface water discharge and level, and groundwater level. The most frequent uses of these data are for investigation, design and operation of municipal and residential water supplies, planning, research, quality assessment, storm drainage, and industrial supply. Approximately 70% of the projects, for which these data are used, are ongoing. Twenty-five percent are completely dependent on having this information while more than 30% are at least 25% dependant on it.

Response to questions concerning data periodicity, format, and publication indicate that the most preferred forms of receiving the information are annual publications and preliminary monthly data on an annual basis, and daily data on a monthly basis respectively.

The replies to the question concerning types of data analyses requested (Question #10) is best explained in its preceding graphic form in Section 5.2.

The following are answers, developed from the overall survey response, to the seven questions posed in Section 5.1.1.

1. Who uses this information? Responses were received as follows: 37% (26) Private Concerns; 42% (30) Civic and Municipal Governments, some of these had been completed for the respondents by their consultants; 21% (15) Federal and Provincial Government Agencies.

2. What is their use for the data? A broad range of uses were indicated, in decreasing order of use they are:

A Municipal and residential withdrawal;
B Water quality assessment;
C Planning and resource evaluation;
D Storm water drainage;
E Investigation and/or research;
F Industrial withdrawal;
G Flood forecasting;
H Flood mitigation using storage
I Monitoring effects of waste disposal
J Water Management;
K Hydroelectric power;
L Low-flow augmentation;
M Bridge design;
N Recreation;
O Irrigation.

3. What presentation of the data is most suitable? Generally, the annual publications of monthly data were preferred, followed by preliminary tabular data.

4. In what time frame is data required? Monthly and daily time frames are preferred.

5. Is the present network coverage sufficient or is more required and if so, where? It was indicated that more coverage is desirable, and the accumulated areas suggested cover the entire province.

6. What is their dependency on this type of data? Twenty-five percent of the respondents are completely

dependent on having this information and more than 30% are dependent to the extent of at least 25% of their operation.

7. What is the dollar value of the programs or operations to which this hydrologic information has contributed? This question was only answered by some of the respondents whose total gross dollar value spent in 1984 only was indicated to be more than $678 million. Section 5.4 discusses this aspect in more detail.

5.4 ECONOMIC RESPONSE

One of the purposes of the questionnaire was to acquire a feeling for the dollar value being spent in Nova Scotia on an annual basis, on projects which require hydrologic information. The question concerned was answered by less than 50% of the respondents. Reasons for not answering were widely varied from not wanting to divulge financial information to not knowing exactly how much was being spent. Nevertheless, from the 44% who did respond, a total of $678 million was indicated. This does not include the costs of operating the networks. It includes the cost of electric power generation at $550 million, the costs for individual concerns to acquire information where none is available, and the operations of the project.

A report, prepared by Acres Consulting Services Limited, "Economic Evaluation of Hydrometric Data", 1977, identified the total national marginal benefits as being $130 million per annum. Some reasons for the discrepancy between the $130 million across Canada and the value arrived at in this report $678 million in Nova Scotia, are the economic changes experienced since 1977, and the difference in methods used to arrive at these amounts. The $130 million was arrived at by apportionment of costs, and estimated savings made possible using various formulae where the $678 million represent the amount of money circulated in Nova Scotia from costs of operation.

5.5 OTHER FINDINGS

Apart from those areas of concern specifically brought out in the questionnaire, respondents requested additional information be made available. The two types of information most requested were water quality data and precipitation data.

Many potential users of hydrologic information contacted in the survey did not respond for some of the following reasons.
A. They were not aware of the existence of this information.
B. They did not know how to use the data.
C. They did not feel these concerns were within their jurisdiction.
D. They lacked understanding of the workings of the hydrologic cycle.

CHAPTER 6

HYDROLOGIC NETWORK REVIEW

6.1 STATISTICAL REVIEW OF EXISTING NETWORKS

With the exception of the Water Planning and Management Branch, Atlantic Region (1978) "Analysis of Low Streamflows in Cape Breton Island, Nova Scotia", and MacLaren Atlantic (1980) "Regional Flood Frequency Analysis for Mainland Nova Scotia Streams", no recent reports could be utilized to define the statistical hydrometric characteristics of the network.

Stations selected for analysis were generally restricted to a minimum of 15 years of record. The stations included are listed in Table 6.1. Regulated streams were not analysed except where noted in the table.

6.1.1. Annual Mean Discharge

Analyses of the annual mean discharges have been performed for active flow stations with at least 15 years of continuous record. From these data, mean annual unit runoffs in millimetres over the respective drainage areas were also computed.

Computations of the mean annual daily discharge, the standard deviation (S.D.), the coefficient of variation (C_v), standard error as percent of the mean and the coefficient of skew (C_s) were performed for all long term stations. The computations were performed over the period of record to 1969 and to 1983 to reflect any changes due to the additional 15 years of data since the last network review.

TABLE 6.1

ACTIVE HYDROMETRIC GAUGING STATIONS ON NATURAL AND REGULATED FLOW STREAMS IN NOVA SCOTIA OPERATING TO 1983 WHICH HAVE SUFFICIENT DATA TO BE ANALYZED FOR THE STATED PERIOD

STATION NUMBER*	DRAINAGE AREA (KM2)	YEARS OF DATA	YEAR DATA STARTED	STATION NAME
01DA001R	167	20	1964	METEGHAN RIVER NEAR METEGHAN RIVER
01DC005R	546	21	1963	ANNAPOLIS RIVER AT WILMOT
01DD004	8.81	17	1967	SHARPE BROOK AT LLOYDS
01DG003	96.9	62	1922	BEAVER RIVER NEAR KINSAC
01DH003	9.07	19	1965	BROOK NEAR ARCHIBALD
01DL001	63.2	14	1970	KELLEY RIVER (MILL CREEK) AT EIGHT MILE FORD
01DN004	298	19	1965	WALLACE RIVER AT WENTWORTH CENTRE
01DO001	249	18	1966	RIVER JOHN AT WELSFORD
01DP004	92.2	18	1966	MIDDLE RIVER AT ROCKLIN
01DR001	177	16	1917	SOUTH RIVER AT ST. ANDREWS
"		18	1966	"
01EA003R	1070	53	1929	TUSKET RIVER AT WILSON'S BRIDGE
01EC001	495	67	1916	ROSEWAY RIVER AT LOWER OHIO
01EE001R	1390	69	1915	MEDWAY RIVER AT CHARLESTON
01ED005	723	15	1969	MERSEY RIVER BELOW GEORGE LAKE
01ED007	295	15	1969	MERSEY RIVER BELOW MILL FALLS
01EF001	1250	68	1916	LA HAVE RIVER AT WEST NORTHFIELD
01EG002	370	18	1966	GOLD RIVER AT MOSHER'S FALLS
01EH003	26.9	58	1926	EAST RIVER AT ST. MARGARETS BAY
01EJ001	146	14	1970	SACKVILLE RIVER AT BEDFORD
01EK001R	650	69	1915	MUSQUODOBOIT RIVER AT CRAWFORD FALLS
01EN002	389	22	1962	LISCOMB RIVER AT LISCOMB MILLS
01EO001	1350	68	1916	ST. MARYS RIVER AT STILLWATER
01ER001	45.1	26	1958	CLAM HARBOUR RIVER NEAR BIRCHTOWN
01FA001	193	18	1966	RIVER INHABITANTS AT GLENORA
01FB001	368	67	1917	NORTHEAST MARGAREE RIVER AT MARGAREE VALLEY
01FB003	357	65	1919	SOUTHWEST MARGAREE RIVER NEAR UPPER MARGAREE
01FH001	120	63	1921	GRAND RIVER AT LOCH LOMOND
01FJ001	199	18	1966	SALMON RIVER AT SALMON RIVER BRIDGE

* - AN 'R' AFTER THE STATION NUMBER DESIGNATES THE STREAM AS REGULATED

Of note is the general increase in the mean, S.D. and C_v all reflecting an increase in the annual runoff and an increase in the variability in the annual mean discharge. The change in the coefficient of skew (C_s) also adds to this trend. The standard error as percent of the mean as explained by Hardison (1969) can be used to appraise the increased accuracy of the data as a result of the increased record length. With long term stations such as shown in Table 6.2 the mean is already quite accurate and additional data do not increase the accuracy by any significant amount.

The statistical parameters in Table 6.2 are also shown in Appendix E-14 "Statistics on the Mean Annual Discharge for Long Term Hydrometric Station for the Period 1934-1983". From this figure, trends can be noted in C_v and C_s from the station mean annual discharge series, with a general decrease in C_v and an increase in C_s from the southwest to the northeast. While no attempt was made to reconfirm the relationship of the C_v of the mean annual discharge data from a basin to the position of the basin centroid with respect to a line extending from Yarmouth to Sydney, as postulated by Ingledow (1970), it was noted that there was a tendency for values of C_v for stations south of 45°15' N latitude with an average of 0.194 to be higher than those to the north of this line. This follows the findings of Coulson (1967) in his division of the province into homogenous areas for regional flood frequency analysis. The fact that north of this line, plus or minus 15' latitude, is where snow on the ground generally remains for much of the winter but with the same significant mid-winter thaws, may have some bearing on the difference in variability in the annual flows and the subsequent increase in the C_v. A third division can be made to include the Cape Breton Highlands where large snowpacks are common with little thawing during the winter months. The average C_v for each of the areas are 0.194 for southwestern Nova Scotia 0.175

A COMPARISON OF STATISTICAL PARAMETERS OF THE ANNUAL MEAN DISCHARGES OF LONG TERM STATIONS WITH THE ADDITIONAL 15 YEARS OF DATA SINCE THE LAST REVIEW

STATION NO.	YEARS	MEAN ANNUAL DISCHARGE (M3/S)		STANDARD DEVIATION		COEFFICIENT OF VARIATION		STANDARD ERROR AS % OF THE MEAN		COEFFICIENT OF SKEW	
		PERIOD TO		PERIOD TO		PERIOD TO		PERIOD TO		PERIOD TO	
		1969	1983	1969	1983	1969	1983	1969	1983	1969	1983
01DG003	62	2.98	3.01	.553	.571	.185	.190	2.70	2.43	-.047	.085
01EA003 (R)	53	32.0	32.7	6.325	6.271	.198	.192	3.13	2.66	.053	.016
01EC001	67	15.7	16.2	2.900	2.999	.184	.186	2.56	2.29	.083	.085
01EE001 (R)	69	40.8	41.4	7.937	7.976	.194	.193	2.64	2.33	.048	-.062
01EF001	68	33.7	34.4	6.913	7.156	.205	.208	2.79	2.52	.091	.121
01EH003	58	.749	.766	.143	.147	.191	.191	2.88	2.51	.062	.110
01EK001 (R)	69	19.4	20.0	3.413	3.920	.176	.196	2.39	2.37	.070	.463
01EO001	68	41.9	43.1	6.664	7.371	.159	.171	2.16	2.08	.019	.390
01FB001	67	16.7	17.3	2.375	2.727	.143	.157	2.01	1.97	.406	.446
01FB003	56	11.9	12.4	1.780	2.017	.150	.163	2.10	2.01	.586	.411
01FH001	63	4.16	4.36	.684	.780	.165	.179	2.35	2.25	.244	.325

(R) -REGULATED FLOW WATERSHED

TABLE 6.2

for northeastern Nova Scotia and 0.160 for the highlands. These three areas follow the hydrologic zones as proposed by Ingledow (1970).

6.1.2 Runoff

Mean annual runoff for the period of record and a variety of periods were computed on the long term discharge stations and compiled in Table 6.3. From this table it can be seen that the past 15 years have had higher runoff than any period in the past 55 years. This may be an indication of the cyclical trend in runoff.

Since the network has only 11 long term stations none of which are located in the Chignecto-Northumberland neck of the peninsula, it was felt that a runoff map could not be produced to reflect the long term picture. Instead it was decided to use the optimum period of 15 years which permits the inclusion of 26 stations over the entire province.

By using the data from these stations a basic runoff map as shown in Appendix E-15 "Isogram of Mean Annual Runoff in Millimetres for Period 1969-1983", could be drawn, however, many areas were not represented, so other more subjective information had to be brought in to fill in the missing areas. By using climate data for the period and taking into consideration the topography and geology of the region, a runoff isogram was produced which represents the mean annual runoff for the period 1969-1983. In order to take out some of the bias that is introduced by the short term data the runoff value as shown in Appendix E-15 "Isogram of Mean Annual Runoff in Millimetres for Period 1969-1983", for each of the 26 stations was displayed at the centroid of the watershed as well as the long term runoff value at each of the 11 long term stations.

TRENDS IN MEAN ANNUAL RUNOFF (mm)

STATION NUMBER	YEAR DATA BEGAN	MEAN FOR PERIOD	10 YEAR MEAN FOR INDICATED PERIODS						15 YEAR	25 YEAR	25 YEAR
			1919-1928	1929-1938	1939-1948	1949-1958	1959-1968	1969-1978	1969-1983	1934-1958	1959-1983
01DG003	1922	980	1006	930	990	980	973	993	998	974	988
01EA003 (R)	1930	965	--	--	903	1007	963	1035	1030	953	1001
01EC001	1918	1030	1011	977	968	1059	1003	1121	1122	1017	1075
01EE001 (R)	1916	941	988	874	900	957	928	943	980	922	959
01EF001	1916	869	805	830	821	906	879	1087	931	859	910
01EH003	1926	898	--	873	874	857	890	942	946	862	924
01EK001 (R)	1916	973	935	907	944	964	980	1074	1084	950	1042
01EO001	1916	1006	980	953	972	1028	983	1087	1107	988	1057
01FB001	1917	1486	1574	1355	1368	1456	1405	1670	1691	1402	1577
01FB003	1919	1097	1042	1020	1022	1083	1064	1236	1266	1039	1185
01FH001	1921	1147	--	1136	1033	1034	1054	1296	1344	1044	1228

Note: - (R) - These stations are on regulated flow streams
Station 01EK001 became regulated in 1968

TABLE 6.3

Comparisons of this map with those published in the past shows an average increase in Cape Breton of 200 mm and with an increase ranging between 20 and 100 mm on the mainland.

6.1.3 Flow Duration Analysis

Flow duration curves have been developed for all active stations in Nova Scotia which have at least 10 years of data. A sample of some curves are shown in Figures 6.1 through 6.3. These flow duration curves show the percentages of time that various rates of discharge have been exceeded. Streamflow characteristics such as dependability of low flows in times of drought, and persistence in times of flood, may be readily obtained from these curves.

The flow duration curve is a useful device for analyzing and predicting the variability of streamflow. Such a curve defines the frequency of occurrence of various rates of flow without regard to chronological sequence. Thus, a major disadvantage of this type of analysis is that it is not possible to tell whether the lowest flows occurred in consecutive periods or were scattered throughout the record. However, by performing the duration analyses by month or season this can be partially overcome.

Flow duration curves have been widely used by engineers to solve problems related to water supply, power developments, sediment production, dilution and disposal of sewage and industrial wastes. The shape of the flow duration curve is indicative of the groundwater contribution to the stream, geologic structure, topography, soil type, vegetation, and other factors. It provides a convenient and appropriate means of relating the characteristics of different streams.

FIGURE 6.1

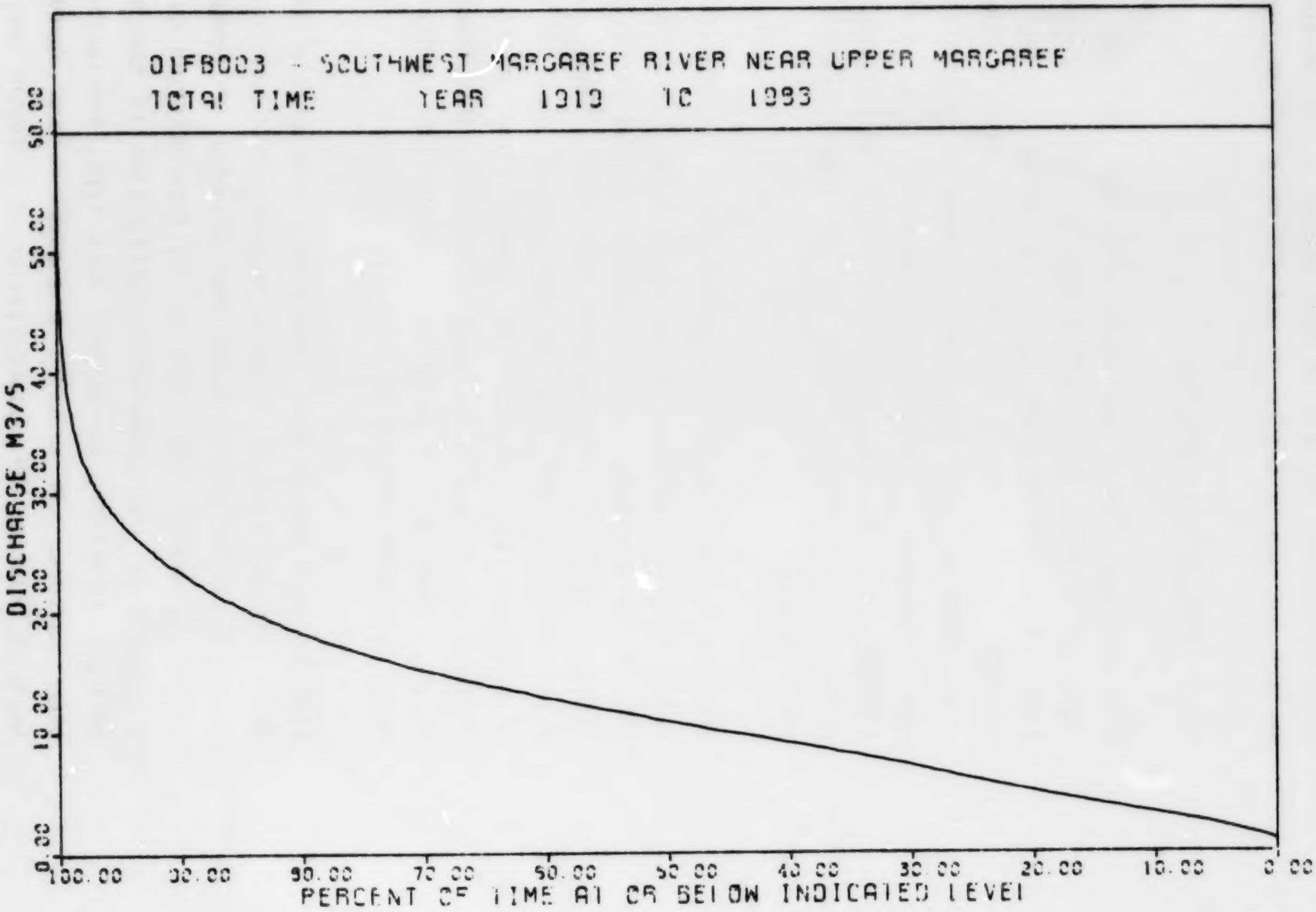

01FB003 - SOUTHWEST MARGAREE RIVER NEAR UPPER MARGAREE
TOTAL TIME YEAR 1919 TO 1983
DISCHARGE M3/S
0.00
10.00
20.00
30.00
40.00
50.00
60.00
PERCENT OF TIME AT OR BELOW INDICATED LEVEL
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00

FIGURE 6.2

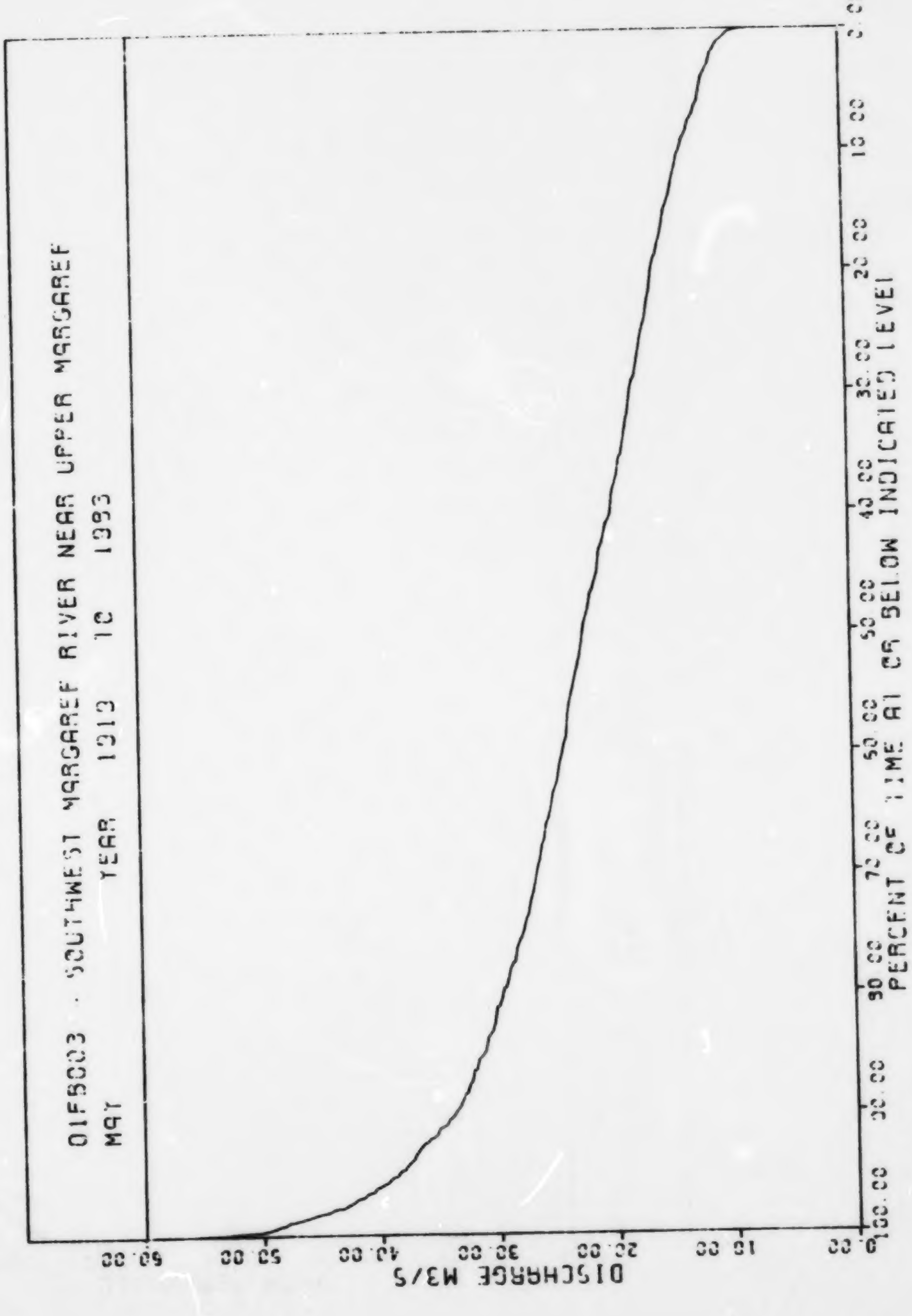
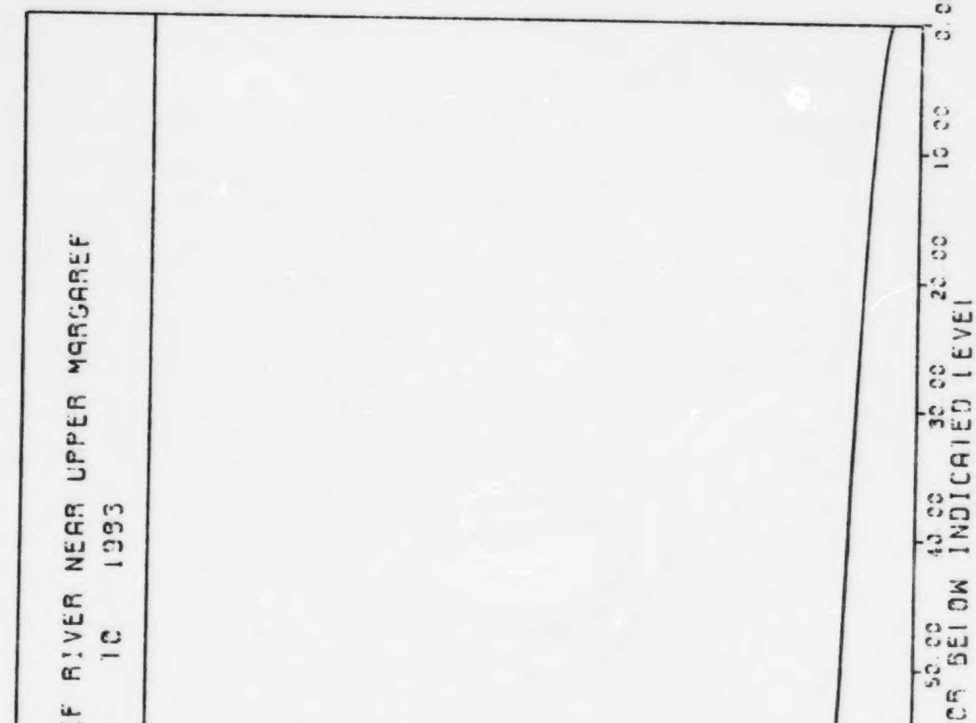

01FB003 . SOUTHWEST MARGAREE RIVER NEAR UPPER MARGAREE
MAY YEAR 1919 TO 1983
DISCHARGE M3/S
0.00
10.00
20.00
30.00
40.00
50.00
60.00
PERCENT OF TIME AT OR BELOW INDICATED LEVEL
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
100.00

FIGURE 6.3


01FB003 - SOUTHWEST MARGAREE RIVER NEAR UPPER MARGAREE
JULY YEAR 1919 TO 1983
DISCHARGE M3/S
0.00
10.00
20.00
30.00
40.00
50.00
60.00
PERCENT OF TIME AT OR BELOW INDICATED LEVEL
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
100.00

6.1.4 Low Flow Frequency Analysis

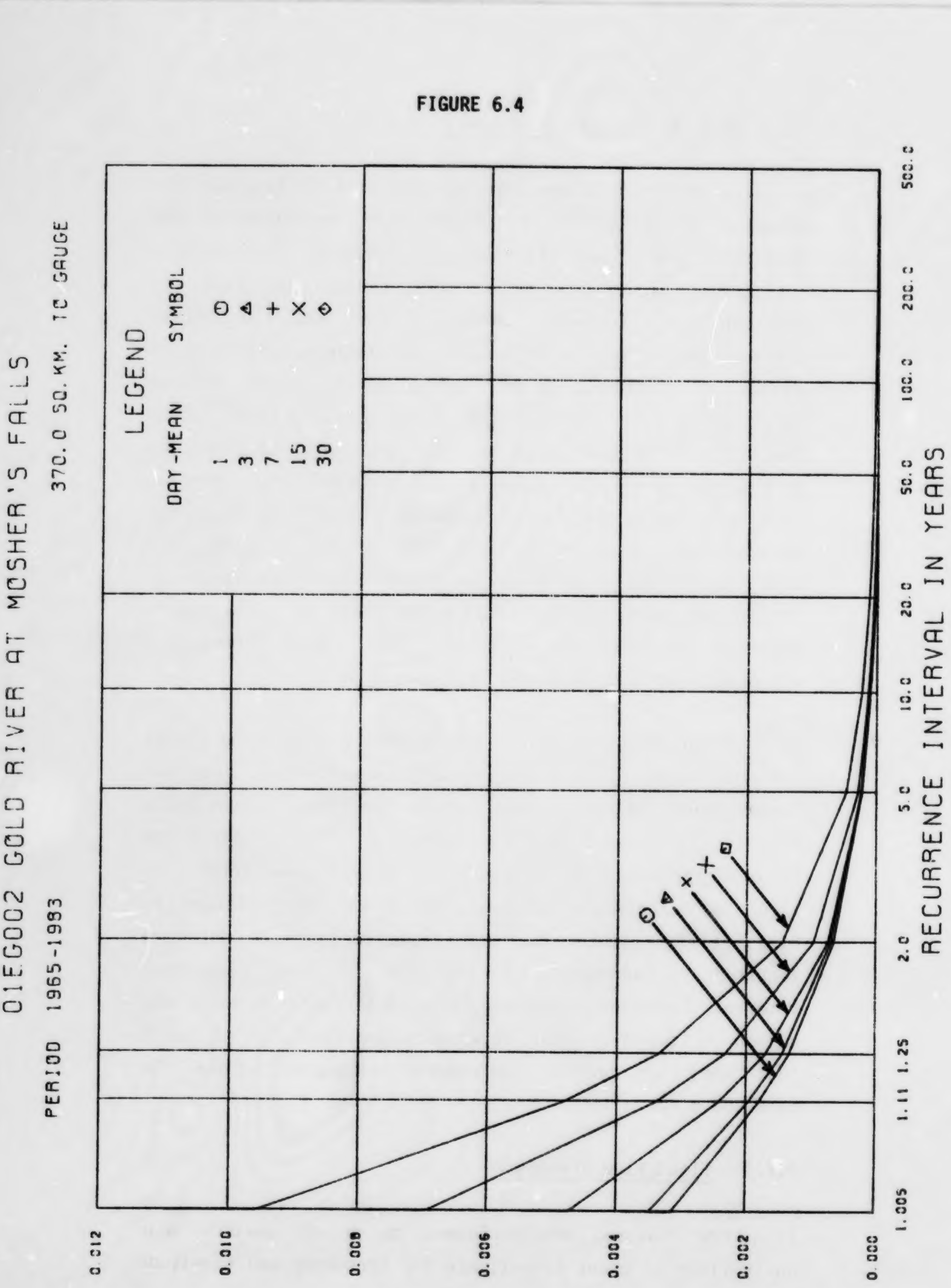
Low flow characteristics are commonly used to forecast the adequacy of a stream to supply the requirements for municipal and industrial water supplies, supplemental irrigation, maintenance of suitable habitat for fish and dilution of disposed wastes. Estimates of these characteristics may be determined by frequency analyses on annual or seasonal minimum mean flows, over various durations, i.e. 1, 7, 15, 30 or 60 day mean low flows. These estimates may be used in conjunction with duration curves to determine reservoir capacities required to provide dependable flows for water supplies. Low flow frequency analyses were computed for all natural flow stations with more than 10 years of data, using the Gumbel III frequency (Condie and Cheng, 1983) distribution on 1, 3, 7, 15 and 30 day mean low flows for each year. The sample curves from these analyses are presented in Figure 6.4.

As noted on the plots of the curves in Figure 6.4 the curves converge after 1:20 years recurrence interval this was common among the rest of the Nova Scotia stream. From Table 6.4, it can be seen that for station 01ED005, Mersey River below George Lake, the 15 and 30 day curves cross before the 1:20 year recurrence interval, which may be explained by Riggs' (1972) premise that more than 20 years of data are required to adequately define the 20 year recurrence interval low flow. However, the difference between the curves at the 1:20 year recurrence interval are so small that they do provide reasonable estimates within the expected error.

6.1.5. Flood Flow Frequency

Frequency analyses are performed on annual maximum mean daily flows in order to estimate the frequency and magnitude

FIGURE 6.4


01EG002 GOLD RIVER AT MOSHER'S FALLS
PERIOD 1965-1983
370.0 SQ. KM. TO GAUGE
LEGEND
DAY-MEAN SYMBOL
1 Θ
3 Δ
7 +
15 X
30 ◇
FLOW (M3/S/KM2)
0.012
0.010
0.008
0.006
0.004
0.002
0.000
1.005
1.11
1.25
2.0
5.0
10.0
20.0
50.0
100.0
200.0
500.0
RECURRENCE INTERVAL IN YEARS
LOW FLOW FREQUENCY ANALYSIS

LOWFLOW FREQUENCY ANALYSIS FOR SELECTED NATURAL FLOW STATIONS IN NOVA SCOTIA

STATION NUMBER	YEARS	1.005 YEAR RECURRENCE INTERVAL				10 YEAR RECURRENCE INTERVAL				20 YEAR RECURRENCE INTERVAL			
		1 DAY DURATION		7 DAY DURATION		7 DAY DURATION		15 DAY DURATION		15 DAY DURATION		30 DAY DURATION	
		LOWFLOW M3/S	UNIT LOWFLOW M3/S/KM2 x .001	LOWFLOW M3/S	UNIT LOWFLOW M3/S/KM2 x .001	LOWFLOW M3/S	UNIT LOWFLOW M3/S/KM2 x .001	LOWFLOW M3/S	UNIT LOWFLOW M3/S/KM2 x .001	LOWFLOW M3/S	UNIT LOWFLOW M3/S/KM2 x .001	LOWFLOW M3/S	UNIT LOWFLOW M3/S/KM2 x .001
01DD004	17	.00754	.855	.0288	3.27	.00009	.010	.00006	.007	0 FLOW AT	T=14 YRS	.00092	.105
01DG003	62	.485	5.00	0.587	6.05	.00837	.086	.0114	.118	.00442	.046	.00656	.068
01DH003	18	.0298	3.29	.0558	6.15	.00026	.028	.00063	.069	0 FLOW AT	T=18 YRS	.00187	.207
01DL001	14	.217	3.43	.344	5.44	.0360	.569	.0411	.651	.0282	.446	.0530	.838
01DN004	20	2.05	6.88	2.48	8.33	.490	1.64	.539	1.808	.517	1.73	.557	1.87
01DO001	18	1.68	6.73	2.18	8.74	.0643	.258	.0807	.324	.0721	.290	.0990	.387
01DP004	18	.651	7.00	.707	7.62	.0149	.160	.0204	.220	.0103	.110	.0159	.171
01DR001	18	1.30	7.32	1.54	8.70	.075	.423	.102	.576	.079	.444	.103	.583
01EC001	68	5.03	10.2	5.75	11.6	.528	1.07	.600	1.21	.427	.863	.555	1.12
01ED005	16	6.73	9.30	7.31	10.1	.603	.835	.713	.986	.573	.792	.503	.695
01ED007	16	2.49	8.44	3.05	10.3	.146	.493	.153	.520	.0600	.202	.106	.358
01EF001	68	10.2	8.17	11.4	9.11	.419	.335	.465	.372	.294	.235	.356	.285
01EG002	18	1.29	3.47	2.04	5.51	.0347	.094	.0432	.117	.0145	.039	.0396	.107
01EH003	58	.237	8.79	.262	9.73	.00943	.351	.0137	.510	.00862	.321	.0117	.433
01EJ001	14	.869	5.96	1.10	7.54	.00449	.307	.0566	.388	.0482	.330	.0581	.398

TABLE 6.4

Continued...

LOWFLOW FREQUENCY ANALYSIS FOR SELECTED NATURAL FLOW STATIONS IN NOVA SCOTIA

STATION NUMBER	YEARS	1.005 YEAR RECURRENCE INTERVAL				10 YEAR RECURRENCE INTERVAL				20 YEAR RECURRENCE INTERVAL			
		1 DAY DURATION		7 DAY DURATION		7 DAY DURATION		15 DAY DURATION		15 DAY DURATION		30 DAY DURATION	
		LOWFLOW M3/S	UNIT LOWFLOW M3/S/KM2 x .001	LOWFLOW M3/S	UNIT LOWFLOW M3/S/KM2 x .001	LOWFLOW M3/S	UNIT LOWFLOW M3/S/KM2 x .001	LOWFLOW M3/S	UNIT LOWFLOW M3/S/KM2 x .001	LOWFLOW M3/S	UNIT LOWFLOW M3/S/KM2 x .001	LOWFLOW M3/S	UNIT LOWFLOW M3/S/KM2 x .001
01EN002	22	4.17	10.7	4.92	12.6	.333	.855	.405	1.04	.249	.640	.310	.797
01EO001	68	9.51	7.05	12.1	8.94	.554	.410	.683	.506	.476	.353	.576	.426
01ER001	25	.161	3.57	.240	5.31	.0033	.073	.00313	.069	.00039	.009	.00309	.069
01FA001	17	1.36	7.04	1.66	8.62	.406	.00210	.470	2.44	.434	2.25	.462	2.40
01FB001	68	5.09	13.8	5.73	15.6	2.13	5.78	2.34	6.35	2.08	5.66	2.47	6.70
01FB003	65	5.62	15.8	6.20	17.4	1.19	3.33	1.28	3.59	1.05	2.95	1.32	3.70
01FH001	64	1.19	9.94	1.55	12.9	.049	.409	.0662	.552	.0375	.312	.0554	.462
01FJ001	19	1.03	5.15	1.20	6.00	.0914	.459	.138	.695	.106	.533	.181	.912

TABLE 6.4 Concluded

of floods in the region. Flood flow analysis is a fundamental tool in the studies performed under the Flood Damage Reduction Program.

Often information on flood frequency is required at points where no hydrometric data are available, or where the existing station has insufficient record for an accurate statistical analysis. To help overcome this, regionalization of flood frequency curves are often performed for each homogeneous zone. Providing the stations used in the regionalization are a fair representation of the characteristics of watersheds in the zone, a regional frequency curve will generally provide more reliable results than those based on a short term single station.

Nonparametric analyses were performed on the annual maximum mean daily discharges from all active hydrometric stations with a period of record greater than 10 years. The data were tested for independence, trend, homogeneity and randomness. The data were also checked for high and low outliers. The results of these tests are summarized in Table 6.5.

Frequency analyses were conducted on the data using the methods described in Condie, Nix and Boone (1979). Where low outliers were identified, the data were analysed with methods described by Pilon and Condie (1982). Other problems with the statistical results were noted and used to explain poor fit with a distribution if noted. A sample flood frequency distribution is shown in Figure 6.5

As noted in Chapter 3, a Regional Flood Frequency Analysis for Nova Scotia streams was produced by MacLaren Atlantic Limited in 1978, using data to 1976. Table 6.6 compares the results from the single station analyses from the above report to the analyses conducted on those stations which are still active, using data to 1983.

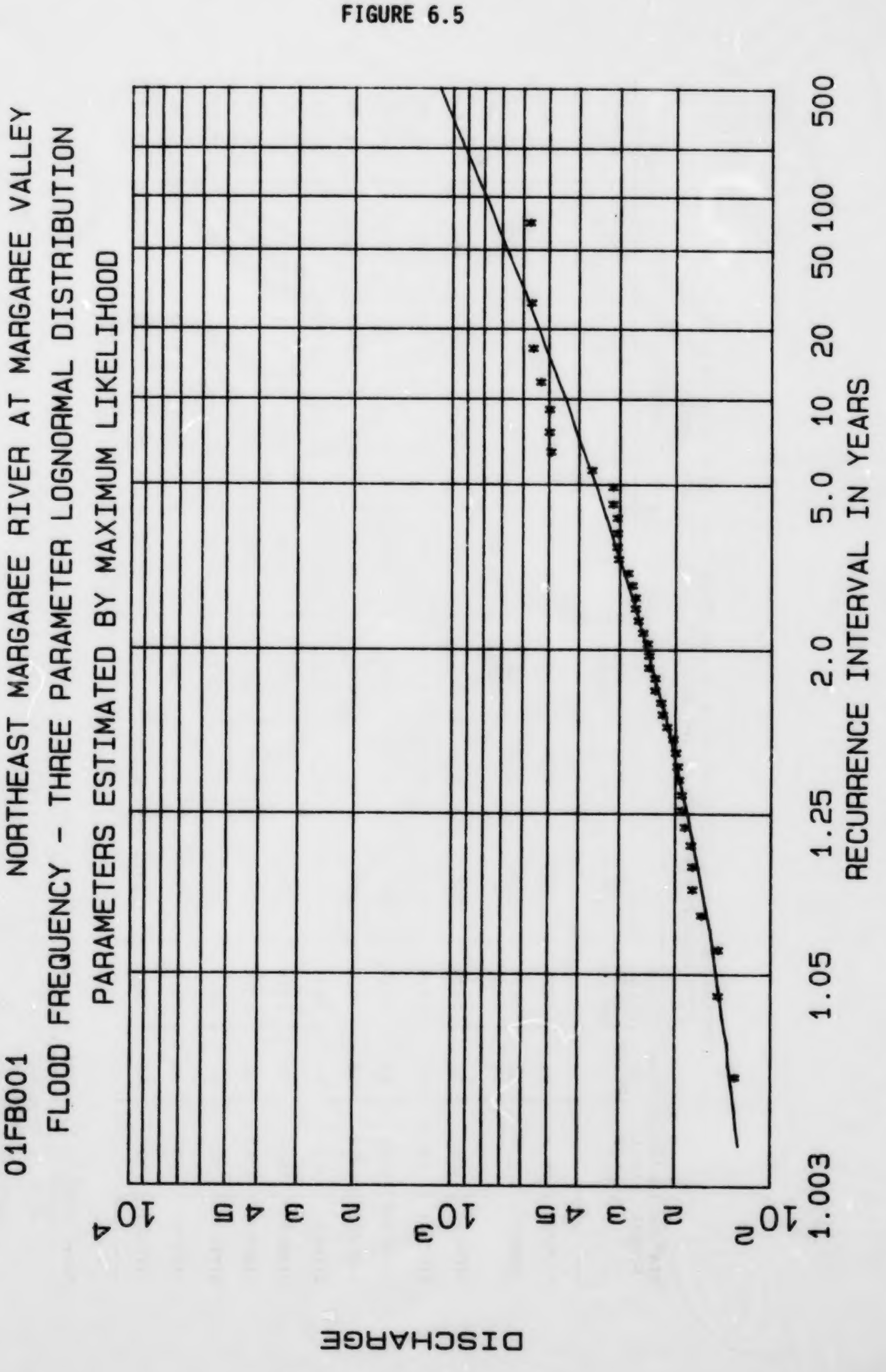
FLOOD FREQUENCEY ANALYSIS
STATISTICAL TESTS ON ANNUAL MAXIMUM MEAN DAILY FLOWS

STATION NUMBER	DRAINAGE AREA (KM2)	YEARS OF DATA	PERIOD	STATION NAME	REMARKS CONCERNING - OUTLIERS - INDEPENDENCE, TREND - HOMOGENEITY, RANDOMNESS
01DA001R	167	20	1964 - 1983	METEGHAN RIVER NEAR METEGHAN RIVER	OK
01DC005R	546	21	1963 - 1983	ANNAPOLIS RIVER AT WILMOT	HOMOGENEITY REJECTED AT 5% SIGNIFICANCE
01DD004	8.81	17	1967 - 1983	SHARPE BROOK AT LLOYDS	OK
01DG003	96.9	62	1922 - 1983	BEAVER RIVER NEAR KINSAC	OK
01DH003	9.07	19	1965 - 1983	FRASER BROOK NEAR ARCHIBALD	OUTLIERS, 1-HIGH, 1-LOW
01DL001	63.2	14	1970 - 1983	KELLEY RIVER (MILL CREEK) AT EIGHT MILE FORD	OK
01DN004	298	19	1965 - 1983	WALLACE RIVER AT WENTWORTH CENTRE	OK
01DO001	249	18	1966 - 1983	RIVER JOHN AT WELSFORD	HOMOGENEITY REJECTED AT 5% SIGNIFICANCE
01DP004	92.2	18	1966 - 1983	MIDDLE RIVER AT ROCKLIN	OK
01DR001	177	16	1917 - 1933	SOUTH RIVER AT ST. ANDREWS	OK
		18	1966 - 1983	" "	OUTLIER, 1-HIGH
01EA003R	1070	53	1929 - 1983	TUSKET RIVER AT WILSON'S BRIDGE	OK
01EC001	495	67	1916 - 1983	ROSEWAY RIVER AT LOWER OHIO	OK
01ED005	723	15	1969 - 1983	MERSEY RIVER BELOW GEORGE LAKE	OK
01ED007	295	15	1969 - 1983	MERSEY RIVER BELOW MILL FALLS	OK
01EE001R	1390	69	1915 - 1983	MEDWAY RIVER AT CHARLESTON	SEASONAL HOMOGENEITY REJECTED AT 1% SIGNIFICANCE LEVEL
01EF001	1250	68	1916 - 1983	LA HAVE RIVER AT WEST NORTHFIELD	OUTLIER, 1-HIGH, LOW NOT PERFORMED
01EG002	370	18	1966 - 1983	GOLD RIVER AT MOSHER'S FALLS	OUTLIER, 1-LOW
01EH003	26.9	58	1926 - 1983	EAST RIVER AT ST. MARGARETS BAY	OUTLIER, 1-HIGH, LOW NOT PERFORMED
01EJ001	146	14	1970 - 1983	SACKVILLE RIVER AT BEDFORD	OK
01EK001R	650	68	1916 - 1983	MUSQUODOBOIT RIVER AT CRANFORD FALLS	OUTLIERS, 2-HIGH, LOW NOT PERFORMED
01EN002	389	22	1962 - 1983	LISCOMB RIVER AT LISCOMB MILLS	OK
01EO001	1350	68	1916 - 1983	ST. MARYS RIVER AT STILLWATER	HOMOGENEITY REJECTED AT 5% SIGNIFICANCE RANDOMNESS REJECTED AT THE 5% LEVEL
01ER001	45.1	26	1958 - 1983	CLAM HARBOUR RIVER NEAR BIRCHTOWN	OK
01FA001	193	18	1966 - 1983	RIVER INHABITANTS AT GLENORA	OK
01FB001	368	67	1917 - 1983	NORTHEAST MARGAREE RIVER AT MARGAREE VALLEY	OK
01FB003	357	65	1919 - 1983	SOUTHWEST MARGAREE RIVER NEAR UPPER MARGAREE	OK
01FH001	120	63	1921 - 1983	GRAND RIVER AT LOCH LOMOND	HOMOGENEITY REJECTED AT 1% SIGNIFICANCE
01FJ001	199	18	1966 - 1983	SALMON RIVER AT SALMON RIVER BRIDGE	OK

NOTE: AN "R" BESIDE A STATION NUMBER DENOTES THAT THE STREAMFLOW IS REGULATED TO SOME EXTENT

TABLE 6.5

FIGURE 6.5


01FB001 NORTHEAST MARGAREE RIVER AT MARGAREE VALLEY
FLOOD FREQUENCY - THREE PARAMETER LOGNORMAL DISTRIBUTION
PARAMETERS ESTIMATED BY MAXIMUM LIKELIHOOD
1.003
1.05
1.25
2.0
5.0
10
20
50 100
500
RECURRENCE INTERVAL IN YEARS
10^2
2
3 4 5
10^3
2
3 4 5
10^4
DISCHARGE

COMPARISON OF QD20 AND QD100 FLOOD FLOWS DETERMINED USING DATA TO 1983 WITH RESULTS PUBLISHED IN THE REGIONAL FLOOD FREQUENCY ANALYSIS

STATION NUMBER	DRAINAGE AREA (KM2)	YEARS OF PEAKS	YEAR PEAKS DATA BEGAN	RFFA		NSHNR		RFFA		NSHNR	
				QD20 (M3/S)	S.E. %	QD20 (M3/S)	S.E. %	QD100 (M3/S)	S.E. %	QD100 (M3/S)	S.E. %
01DG003	96.9	62	1922	54.1	9.16	53.0	8.70	71.9	13.30	70.2	12.60
01DR001*	177	34	1917	119.	12.40	116.	12.80	157.	18.10	158.	18.80
" "		18	1966	-	-	125.	24.80	-	-	199.	36.90
01EA003R	1070	52	1930	346.	9.63	340.	9.33	453.	13.80	446.	13.40
01EC001	495	67	1916	122.	8.87	133.	11.60	164.	13.00	186.	16.90
01EE001R	1390	68	1916	295.	10.20	288.	9.26	413.	14.90	399.	13.80
01EF001	1250	68	1916	459.	11.00	445.	10.20	663.	15.90	634.	14.80
01EH003	26.9	58	1926	20.3	16.60	19.6	15.50	33.7	23.00	32.2	21.50
01EK001R	650	68	1916	234.	9.81	228.	9.80	286.	12.70	317.	14.10
01EO001	1350	68	1916	694.	7.73	689.	7.26	892.	11.40	881.	10.70
01FB001	368	67	1917	272.	7.06	280.	7.03	343.	10.40	355.	10.40
01FB003	357	65	1919	51.5	4.42	53.4	4.50	59.2	6.63	61.9	6.76
01FH001	120	63	1921	29.2	6.29	29.6	6.38	35.4	9.25	36.4	9.43

Note: QD20 - 1:20 year mean daily flood flow
QD100 - 1:100 year mean daily flood flow
RFFA - Regional Flood Frequency Analysis for Mainland Nova Scotia (1980)
- Data used in this report was to 1978
NSHNR - Nova Scotia Hydrologic Network Review
- Data used in this report was to 1983
R - Streamflow at this station is regulated to some extent

* The frequency analyses for 01DR001 were performed on the discontinuous data for the periods 1917-1933 and 1966-1983 for comparison only with the RFFA

TABLE 6.6

As shown in Table 6.6, all results are well within the 95% confidence limits and, in most cases, they are within the standard error of estimate of the curves produced in the 1978 report. Even the station 01DR001, South River at St. Andrews, shows a reasonable comparison when only the last 18 continuous years are used rather than the 34 years from two discontinuous periods as were used in the original analysis.

6.1.6 Correlation of Paired Stations

It is not possible to gauge every stream in anticipation that flow records will be required at some future date, and even so, the likelihood that the data would have been collected at the required site is highly remote. In designing a network to satisfy the long term demands for the resource, a proper mix of streams must be selected; long, intermediate and short term stations with a good cross-section of the physiographic attributes in each homogeneous zone should be selected.

If one can use correlation analysis to infer the long-term characteristics of river flow from the available short record , then it is possible to move the resources used for that short term station to establish a new station and consequently refine the knowledge of the area. This is the base station/roving station approach to covering all areas over time.

Using the computer program package SPSS (Statistical Programs for the Social Sciences) (NIE et al 1970) linear correlations have been performed on all long term natural flow stations with short term stations selected from the general areas around the long term station. These analyses were performed on the mean annual, the annual maximum mean daily, the 30 day low flow mean and the 60 day low flow mean discharges. The results of these are presented in Table 6.7. Appendix E-16 "Correlation Coefficients on Mean Annual Discharges", shows the relationship between selective stations via their correlation coefficients on the mean annual discharge. A correlation is considered good if it can explain 81% of the variance, i.e., $R^2 = 0.81$ or $R = 0.90$.

Station pairs which showed reasonably good correlations in Table 6.7 were analyzed further using monthly mean data. Table 6.8 summarizes these analyses. In most cases the correlation coefficients remained high throughout most of the year. Poorer correlations appeared most frequently during the low flow periods which normally fall in the months of July through September. During periods of low flow as the influence of precipitation is reduced, the geology and the percentage of lake and swamp are the controlling factors. The poor correlation between stations during the lowflow period points out a need for more information on the hydrologic processes during the time when the driving force of the hydrologic cycle is not precipitation but the release of stored water in lakes, swamps and groundwater aquifers. A denser network of stations during the lowflow period in conjunction with more groundwater monitoring wells could provide this valuable data base from which this understanding would come.

Two station pairs show reasonably good correlation using mean monthly data. These station pairs are 01EF001 - LaHave River with 01EG002 - Gold River and 01EO001 - St. Mary's River with 01EN002 - Liscomb River.

CORRELATION OF FLOWS BETWEEN ACTIVE LONG TERM AND SHORTER TERM STATIONS USING DATA COLLECTED FROM 1969 - 1983

STATION NO.		ANNUAL MEAN FLOW		ANNUAL MAXIMUN MEAN DAILY FLOW		ANNUAL 30 DAY MEAN LOW FLOW		ANNUAL 60 DAY MEAN LOW FLOW	
INDEPENDENT STATION	DEPENDENT STATION	CORRELATION COEFFICIENT (R)	STANDARD ERROR (S.E)	CORRELATION COEFFICIENT (R)	STANDARD ERROR (S.E.)	CORRELATION COEFFICIENT (R)	STANDARD ERROR (S.E.)	CORRELATION COEFFICIENT (R)	STANDARD ERROR (S.E.
01EC001	01ED005	.962	1.260	.667	9.84	.894	.784	.939	.838
"	01ED007	.922	3.011	.481	11.6	.825	.990	.832	1.35
"	01EF001	.926	2.940	.758	8.60	.908	.735	.935	.869
01EF001	01EG002	.958	2.223	.786	39.6	.893	1.16	.962	.784
"	01ED005	.945	2.532	.621	11.6	.907	.833	.962	1.08
"	01ED007	.922	3.018	.668	9.54	.910	.408	.936	.438
01EH003	01EG002	.858	1.117	.564	16.4	.667	.602	.694	1.06
"	*01EJ001	.924	.060	.678	12.3	-.002	1.71	-.170	2.30
"	01DG003	.920	.262	.570	8.32	-.103	.189	-.210	.292
01DG003	*01EJ001	.960	.188	.940	3.45	-.084	.189	-.146	.295
01E0001	01EN002	.950	2.681	.922	20.9	.870	.955	.882	1.23
"	01DP004	.906	3.630	.698	5.52	.882	.144	.877	.231
"	01DR001	.926	3.247	.884	15.3	.987	.105	.937	.290
"	01ER001	.803	5.106	.412	186	.887	2.98	.905	3.47
"	01DH003	.813	4.993	.619	.472	.866	.014	.902	.019

* - SOME STATIONS HAVE ONLY 14 YEARS OF DATA

TABLE 6.7

Continued...

CORRELATION OF FLOWS BETWEEN ACTIVE LONG TERM AND SHORTER TERM STATIONS USING DATA COLLECTED FROM 1969 - 1983

STATION NO.		ANNUAL MEAN FLOW		ANNUAL MAXIMUN MEAM DAILY FLOW		ANNUAL 30 DAY MEAN LOW FLOW		ANNUAL 60 DAY MEAN LOW FLOW	
INDEPENDENT STATION NO.	DEPENDENT STATION NO.	CORRELATION COEFFICIENT (R)	STANDARD ERROR (S.E.)	CORRELATION COEFFICIENT (R)	STANDARD ERROR (S.E.)	CORRELATION COEFFICIENT (R)	STANDARD ERROR (S.E.)	CORRELATION COEFFICIENT (R)	STANDARD ERROR (S.E.)
01DN004	*01DO001	.973	.404	.580	39.5	.957	.324	.914	.711
"	01DL001	.825	1.148	.016	12.6	.837	.114	.928	.137
"	01DH003	.905	.862	.613	.457	.913	.011	.913	.018
"	01DP004	.860	1.037	.746	32.3	.930	.409	.896	.777
01DO001	01DH003	.907	.731	.705	.426	.948	.009	.914	.019
"	01DP004	.851	.913	.875	13.7	.956	.294	.848	.810
01FB001	01FB003	.595	1.359	.703	46.0	.640	.888	.700	1.25
"	01FA001	.515	2.316	.196	15.0	.275	.595	.400	1.02
"	01FH001	.723	1.867	.854	33.7	.274	1.11	.378	1.63
"	01FJ001	.732	1.841	.588	52.4	.473	1.02	.357	1.64
01FB003	01FA001	.694	1.219	.404	14.0	.837	.338	.695	.801
"	01FH001	.681	1.239	.472	8.12	.567	1.24	.402	1.71
"	01FJ001	.585	1.372	.304	8.77	.798	.907	.335	1.76
01FH001	01FA001	.884	.569	.299	14.6	.667	.461	.789	.684
"	01FJ001	.801	.424	.449	6.52	.844	.251	.947	.299

* - SOME STATIONS HAVE ONLY 14 YEARS OF DATA

TABLE 6.7 Concluded

CORRELATION COEFFICIENTS OF MEAN MONTHLY FLOWS BETWEEN LONG TERM AND SHORT TERM HYDROMETRIC STATIONS
USING DATA FROM 1969 TO 1983

INDEPENDENT STATION	DEPENDENT STATION	MONTH											
		JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
01EC001	01ED005	.954	.931	.861	.819	.866	.867	.868	.701	.701	.933	.912	.874
01EF001	01ED005	.956	.882	.915	.872	.953	.848	.906	.807	.874	.891	.897	.875
01EF001	01EG002	.934	.958	.955	.904	.984	.956	.959	.985	.957	.970	.963	.944
01EO001	01EN002	.977	.971	.963	.948	.982	.946	.873	.942	.881	.960	.961	.952
01DO001	01DN004	.969	.961	.936	.863	.954	.895	.730	.983	.919	.902	.874	.885

TABLE 6.8

From this exercise, it can be seen that the network is either sparse or well diversified and that simple linear regression should not generally be used in Nova Scotia to transfer the long term characteristics from one basin to another. The utilization of multiple regression analysis using generalized least squares techniques as recommended by Stedinger and Tasker (1985) for the transfer of data to ungauged streams should be examined and further work performed before recommendations are made to discontinue any stations on this basis.

6.2 COMPUTATION OF UNCERTAINTY FUNCTIONS FOR SELECTED GAUGING STATIONS

This section was written by W.O. Thomas Jr., Chief, Hydrology Division, and L.C. Cheng, Systems Analysist, Hydrology Division, Inland Waters Directorate, Environment Canada, Ottawa. An evaluation of the accuracy of streamflow data is important in the apportionment of water supply and in the design of water resources projects. A search of the available literature indicates that limited research has been conducted in determining the accuracy of instantaneous or daily mean streamflows determined from a stage-discharge relation. Recent research by Moss and Gilroy (1980) has suggested the use of Kalman-filtering techniques to determine this desired accuracy.

The accuracy of instantaneous streamflow as a function of the number of discharge measurements and/or visits per season or year can be estimated using Kalman-filtering techniques (Gelb, 1974) and information transfer by regression analysis. This functional relationship between accuracy of the data and the level of effort required to obtain these data is called an uncertainty function. Kalman-filtering is a statistical technique for combining information from discharge measurements and the stage-discharge relation (rating curve) to provide estimates of instantaneous or daily mean discharges and the variances of these discharges. In this study only the variance of instantaneous discharge is evaluated. As explained later, the variance of the instantaneous discharge is equivalent to the variance of the daily mean discharge. The Kalman-filtering technique is applicable when observed stage records are available and discharge is estimated from the rating curve. The uncertainty in the rating curve is determined by analyzing a time series of residuals representing the difference in logarithmic units between the measured discharge and the rating-curve discharge. This time series of residuals is analyzed to determine three site-specific parameters needed to compute the uncertainty functions. These parameters are described in greater detail in Appendix "D" and their computation is discussed in a later section of this report.

When stage records are missing during periods of equipment malfunction, the variance of the discharge is estimated using regression analysis and daily mean discharges at nearby sites. This requires the determination of additional parameters such as:

1) The percentage of lost stage record for a given visitation frequency;
2) An estimate of at-site variability in the daily mean discharges (coefficient of variation) at the site of interest; and
3) A measure of correlation of daily mean discharges between the site of interest and nearby sites. These parameters are described in Appendix "D" and their use is illustrated in a later section of the report.

Infrequently neither observed stage data at the site of interest nor suitable daily mean discharges at nearby sites are available. During these periods the variance of the discharge is estimated on the basis of the coefficient of variation for the site of interest. In addition to the technical description in Appendix "D", Moss and Gilroy (1980) and Fontaine and others (1984) provide the theoretical background and illustrate the technique.

The computation of uncertainty functions provides a quantitative evaluation of the error in the instantaneous discharge (as well as daily iron discharge) at each station, provides guidance on how resources could be redistributed among stations so that more discharge measurements are made at stations with unstable rating curves and less measurements at those with stable rating curves, and allows the manager of the stream gauging program to evaluate the trade-off between the accuracy of the streamflow data and the cost of obtaining these data. The computation of uncertainty functions is an integral step in determining the cost-effective operation of the stream gauging program.

6.2.1 Background Data Base

Uncertainty functions were computed for the following five stations to illustrate the application of the technique.

Roseway River at Lower Ohio (01EC001)	495 km^2
Mersey River below George Lake (01ED005)	723 km^2
East River at St. Margarets Bay (01EH003)	26.9 km^2
Liscomb River at Liscomb Mills (01EN002)	389 km^2
Southwest Margaree R near Upper Margaree (01FB003)	357 km^2

These stations are representative of a range in channel conditions and accuracy of the rating curves. Most of these stations have fairly long records with Mersey River (station 01ED005) having the shortest length of record, 1968 to present. The long periods of operation for these stations ensure that sufficient discharge measurement data are available for defining the uncertainty functions. At least 50 discharge measurements are needed to adequately define the statistical parameters for the uncertainty functions. The availability of discharge measurements is summarized in Table 6.9 for the five stations.

The discharge measurements were obtained from the Measurements File of the Water Survey of Canada (Environment Canada, 1984). Measurements obviously affected by backwater from ice or with obvious input errors were not used in the analysis. As shown in the table above, only a small percentage of the total number of measurements were affected in this way.

TABLE 6.9

AVAILABILITY OF DISCHARGE MEASUREMENTS

Station Number	Number of measurements available	Number of measurements deleted	Number of measurements used in the analysis
01EC001	269	7	262
01ED005	51	1	50
01EH003	136	1	135
01EN002	76	2	74
01FB003	238	3	235

During periods when the stage recorder is functioning properly, the uncertainty function is computed by analyzing a time series of residuals representing the difference in logarithmic units between the measured discharge and the rating-curve discharge. However during periods of lost stage record, the uncertainty associated with estimating the discharge from daily mean discharges at nearby sites is added to the uncertainty (variance) of the rating curve. As noted earlier the percentage of lost stage record for a given visitation frequency is required in order to compute the uncertainty function during periods of lost stage record. This information was obtained from Weibe and Terzi (1985) and by consulting with engineers and technicians familiar with these stations. Using information from these two sources, it was determined that 4.0 percent of the stage record is lost each year if the stations are visited 10 times. The description of how this information is used is given in a later section of the report.

6.2.2 Computational Procedures

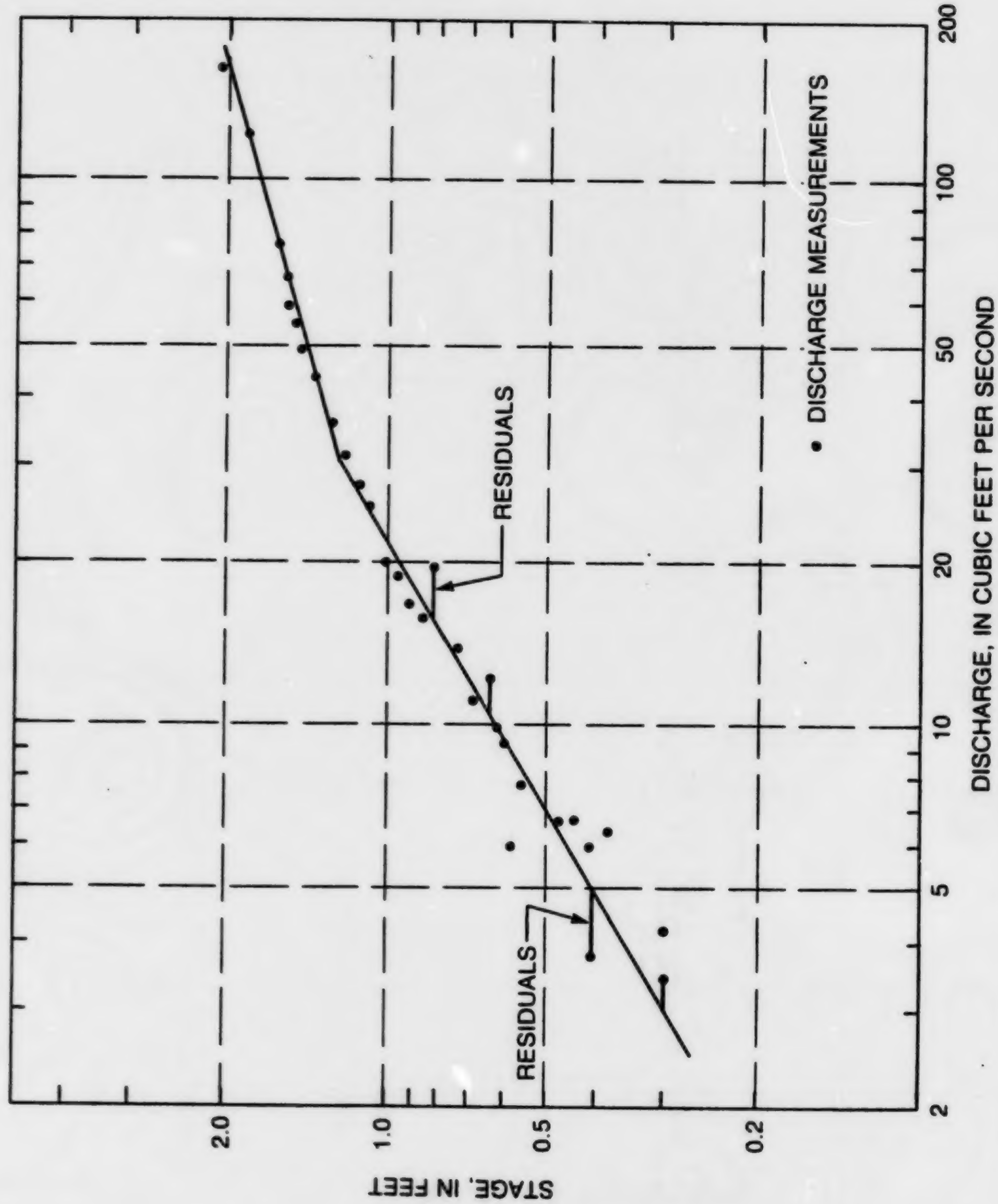
Computer programs for defining the uncertainty functions are described by Thomas and others (1985). The computation of the uncertainty functions require the following steps:

1. Define a long-term stage-discharge relation (rating curve) using at least 50 discharge measurements indicative of present channel conditions. Compute a time series of residuals as the difference between the measured discharge and the rating-curve discharge. An example of a logarithmic stage-discharge relation for East River at St. Margarets Bay is given in Figure 6.6. The residuals are indicated as horizontal deviations from the stage-discharge relation.

2. Analyze the time series of residuals to determine the one-day autocorrelation coefficient (RHO) and the process variance (p). Both RHO and p are defined in Appendix D. An example of a time series of residuals for East River at St. Margarets Bay is shown in Figure 6.7: Note that one rating curve provides an unbiased rating for the period of record from 1925 to 1983.

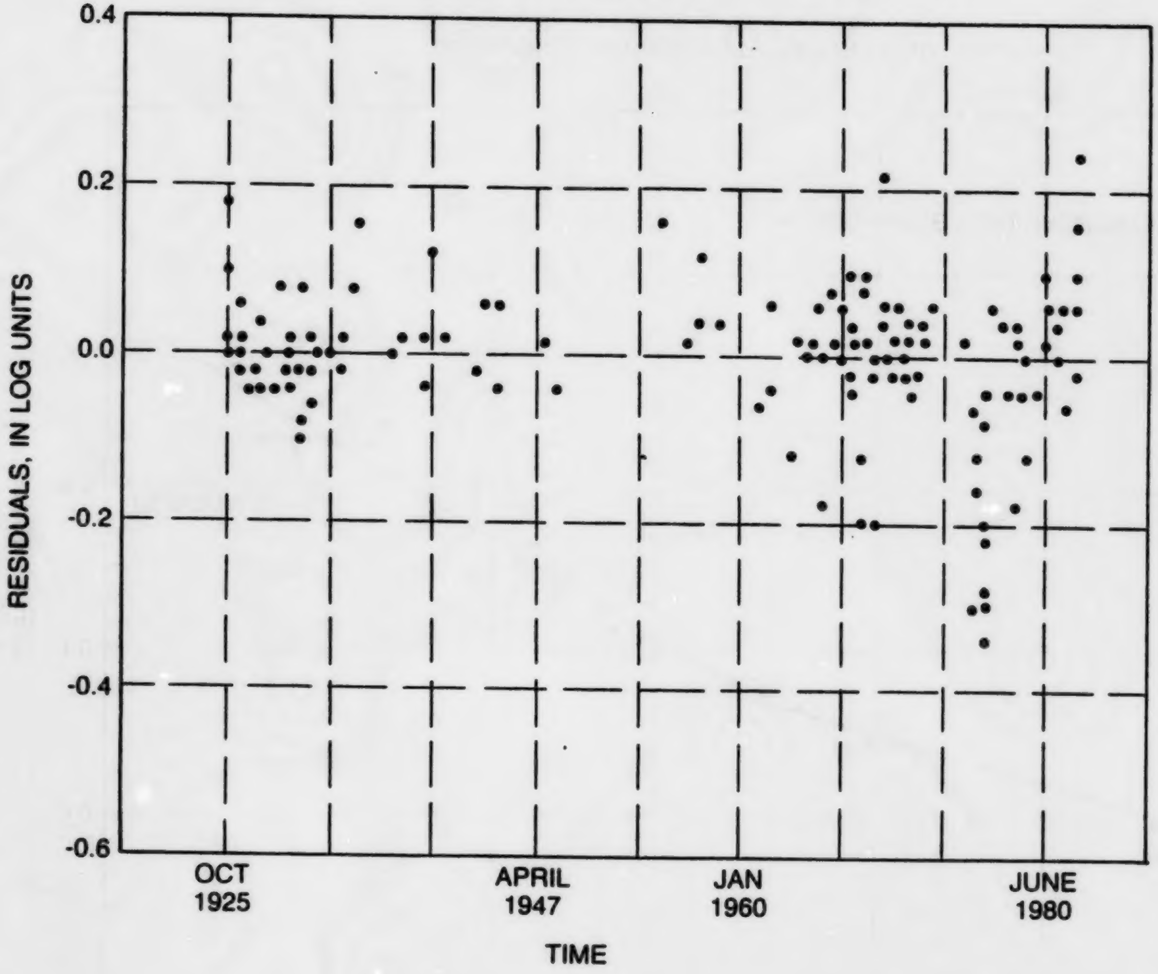
FIGURE 6.6

FIGURE 6.6



STAGE-DISCHARGE RELATION FOR EAST RIVER AT ST. MARGARETS BAY (01EH003).

FIGURE 6.7



TIME SERIES OF RESIDUALS FOR EAST RIVER AT ST. MARGARETS BAY (01EH003)

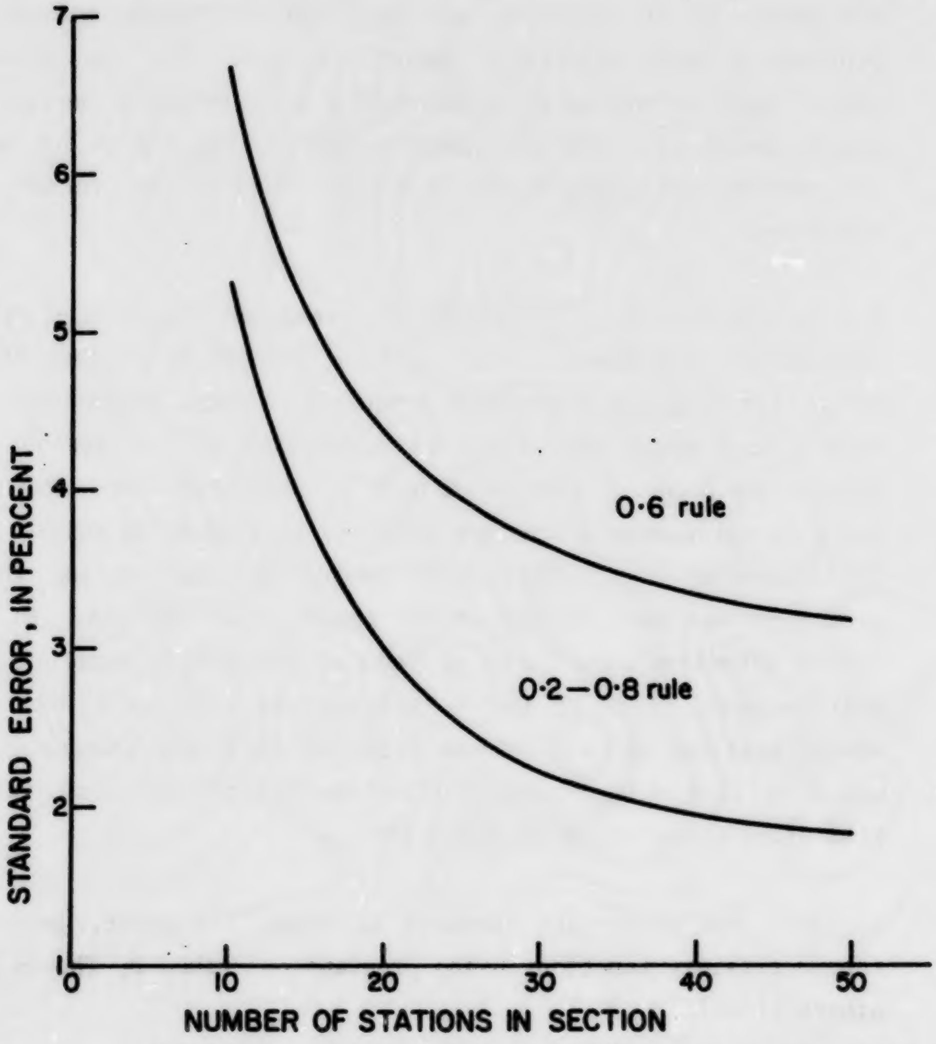
FIGURE 6.7

3. Determine the discharge measurement standard error using Figure 6.8 (Carter and Anderson, 1963). Figure 6.8 relates the standard error of the discharge measurement to the number of verticals in the measuring cross section and the method of obtaining the mean velocity in the vertical subsection (i.e. .6 depth or .2 and .8 depth). A conservative estimate of the standard error of 5.0 percent was used for all measurements. This is the standard error that would result if each measurement had about of 20 sections and used the .6 depth method of determining mean velocity. Twenty sections are the minimum number used in discharge measurements made by Water Resources Branch personnel. The measurment variance, RHO and p are used to compute the uncertainty function when stage record is available.

4. Determine the coefficient of variation (C_v), the cross correlation coefficient (CROSS) and the percentage of lost stage record for a given visitation frequency. These parameters are needed to compute the uncertainty function during periods of lost stage record. The parameters C_v and CROSS were computed using 25 daily mean discharges selected at random throughout the 1982 calendar year. This small sample for determining these parameters was used because of the manual entry of data. In the future automated data entry procedures and larger sample sizes will be used. Each of the 5 stations was correlated with two nearby stations and the maximum value of CROSS was selected. As noted earlier 4.0 percent lost stage record was used for a visitation frequency of 10 times per year.

5. With the parameters computed in steps 1-4 above, generate the uncertainty functions using programs described by Thomas and others (1985).

FIGURE 6.8



Relationship between the standard error of the discharge measurement and the number of stations in the measuring cross section and the method of computing mean velocity.

6.2.3 Presentation of Results

The parameters needed to compute the uncertainty functions are:

1) The one-day autocorrelation coefficient (RHO);
2) The process variance (p);
3) The measurement variance;
4) The percent of lost stage record for a given visitation frequency;
5) The coefficient of variation (C_v) for the station of interest and the cross correlation coefficient (CROSS) between the station of interest and nearby stations.

The measurement variance is 0.000471 squared logarithmic (base 10) units which corresponds to a standard error of 5.0 percent for all measurements. The percentage of lost stage record is 4.0 for 10 visits per year. The remaining parameters are summarized below for the five stations. The uncertainty functions generated from these parameters are shown in Figures 6.9 through 6.13

Station Number	RHO	p (log units)^2	C_v	CROSS
01EC001	0.9945	0.005578	0.915	0.946
01ED005	.8014	.001165	1.024	.901
01EH003	.9836	.008359	1.407	.992
01EN002	.8447	.001797	1.251	.974
01FB003	.9778	.000799	.972	.847

The values of CROSS may be inflated because they are based on only 25 daily mean discharges for one calendar year. The values of CROSS should be based on several years of daily mean discharges. In the near future, a computer program will be available for computing CROSS based on an adequate sample size. The process variances (p) are in squared logarithmic units (base 10) and represent the uncertainty in the rating curve relation

FIGURE 6.9

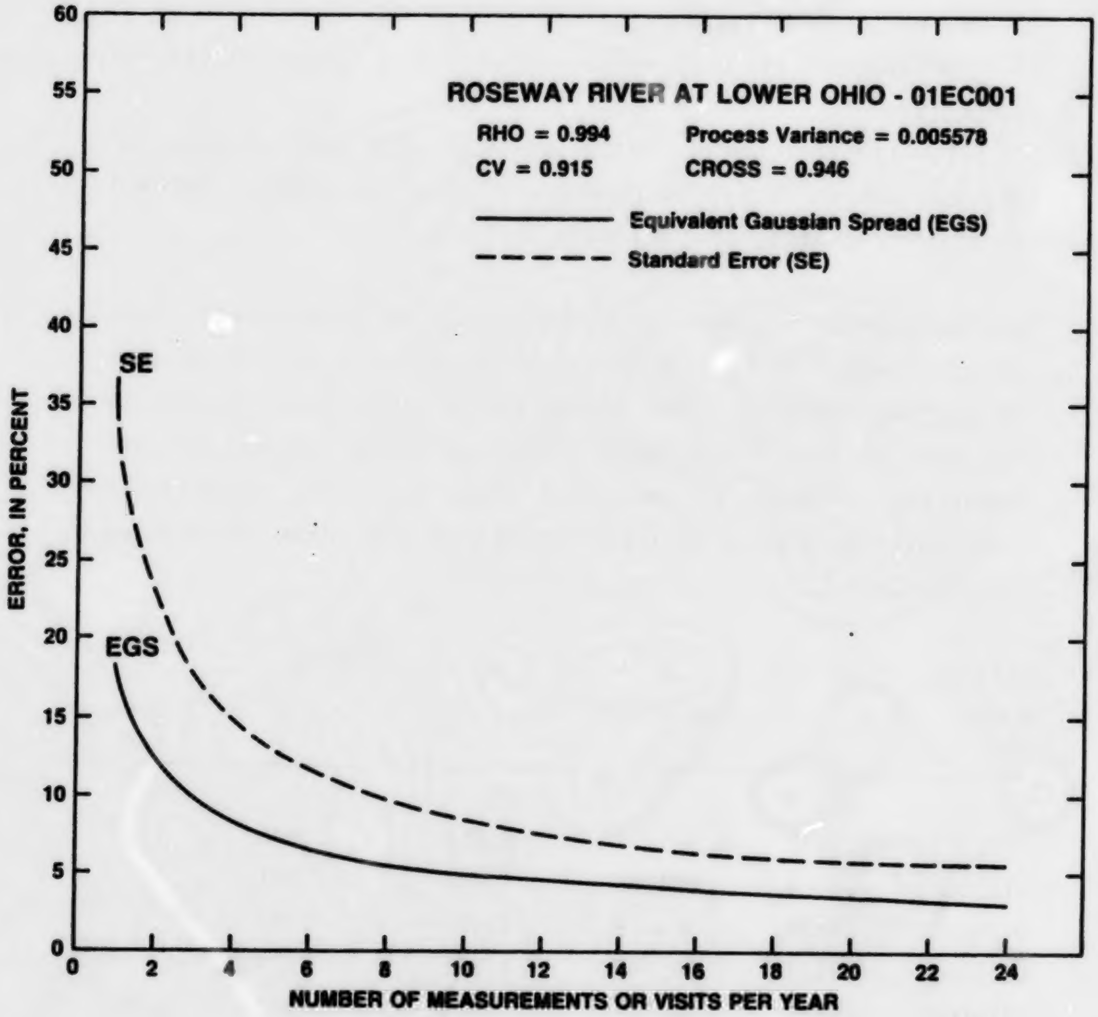

ROSEWAY RIVER AT LOWER OHIO - 01EC001
RHO = 0.994
Process Variance = 0.005578
CV = 0.915
CROSS = 0.946
Equivalent Gaussian Spread (EGS)
Standard Error (SE)
SE
EGS
ERROR, IN PERCENT
0
5
10
15
20
25
30
35
40
45
50
55
60
0
2
4
6
8
10
12
14
16
18
20
22
24
NUMBER OF MEASUREMENTS OR VISITS PER YEAR

FIGURE 6.10

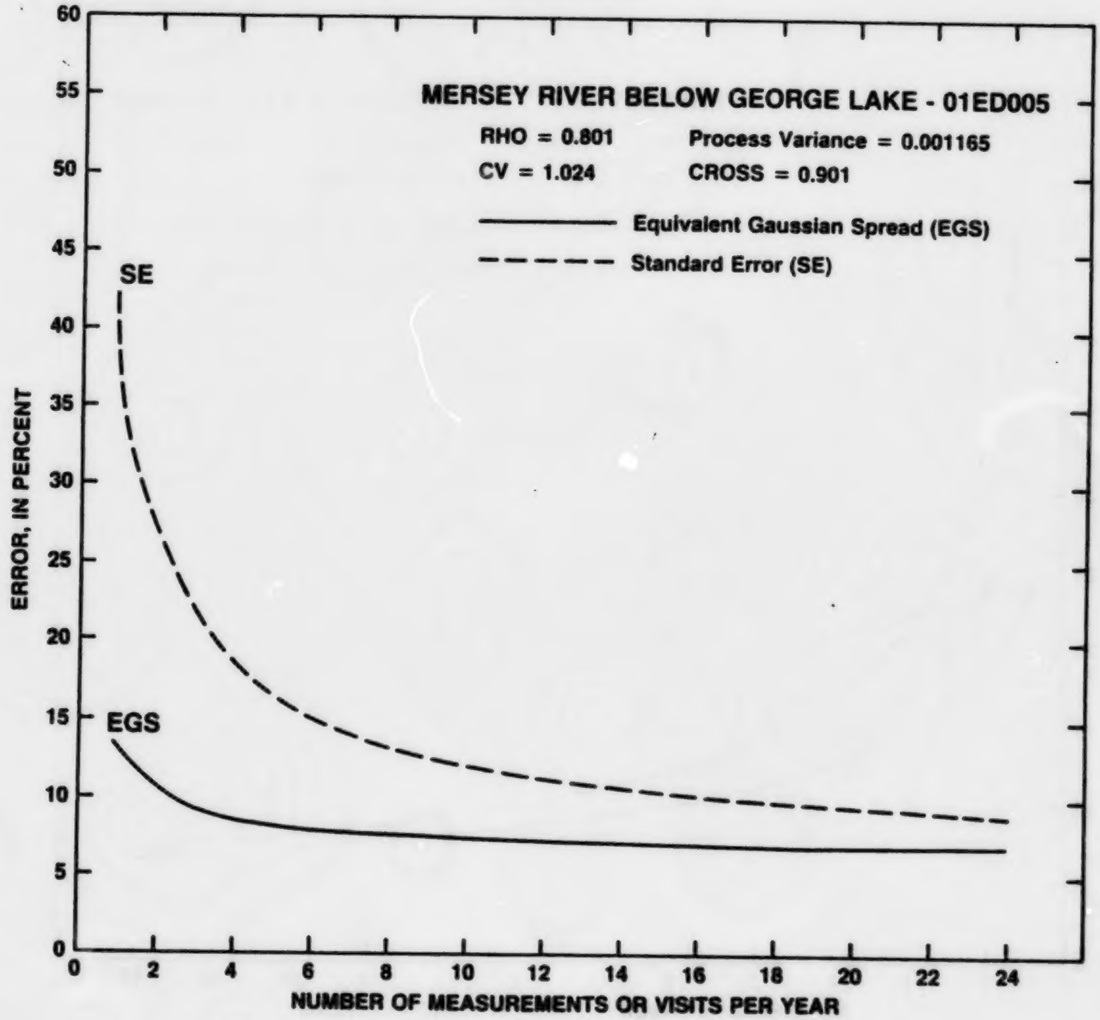

MERSEY RIVER BELOW GEORGE LAKE - 01ED005
RHO = 0.801
Process Variance = 0.001165
CV = 1.024
CROSS = 0.901
Equivalent Gaussian Spread (EGS)
Standard Error (SE)
SE
EGS
ERROR, IN PERCENT
0
5
10
15
20
25
30
35
40
45
50
55
60
0
2
4
6
8
10
12
14
16
18
20
22
24
NUMBER OF MEASUREMENTS OR VISITS PER YEAR

FIGURE 6.11

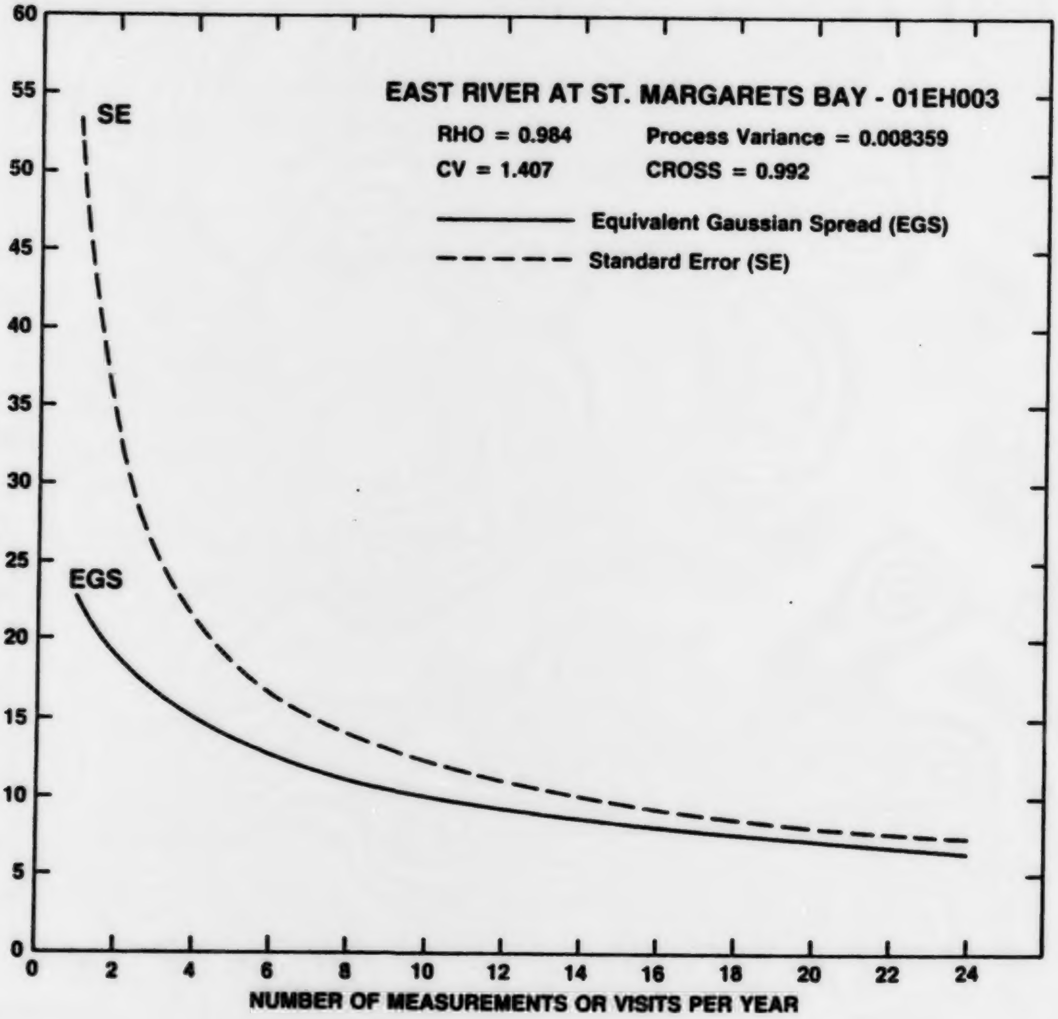

EAST RIVER AT ST. MARGARETS BAY - 01EH003
RHO = 0.984
Process Variance = 0.008359
CV = 1.407
CROSS = 0.992
Equivalent Gaussian Spread (EGS)
Standard Error (SE)
SE
EGS
ERROR, IN PERCENT
0
5
10
15
20
25
30
35
40
45
50
55
60
0
2
4
6
8
10
12
14
16
18
20
22
24
NUMBER OF MEASUREMENTS OR VISITS PER YEAR

FIGURE 6.12

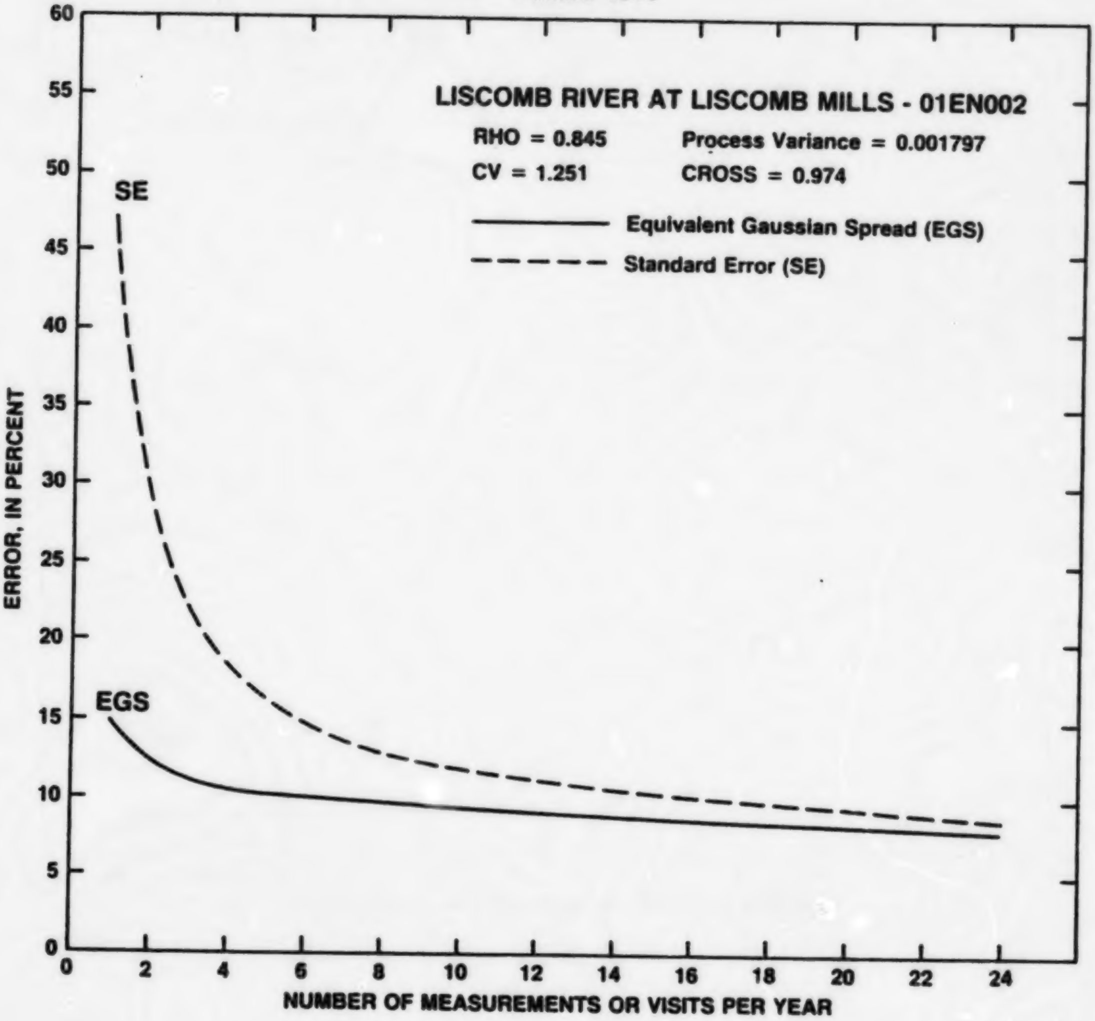
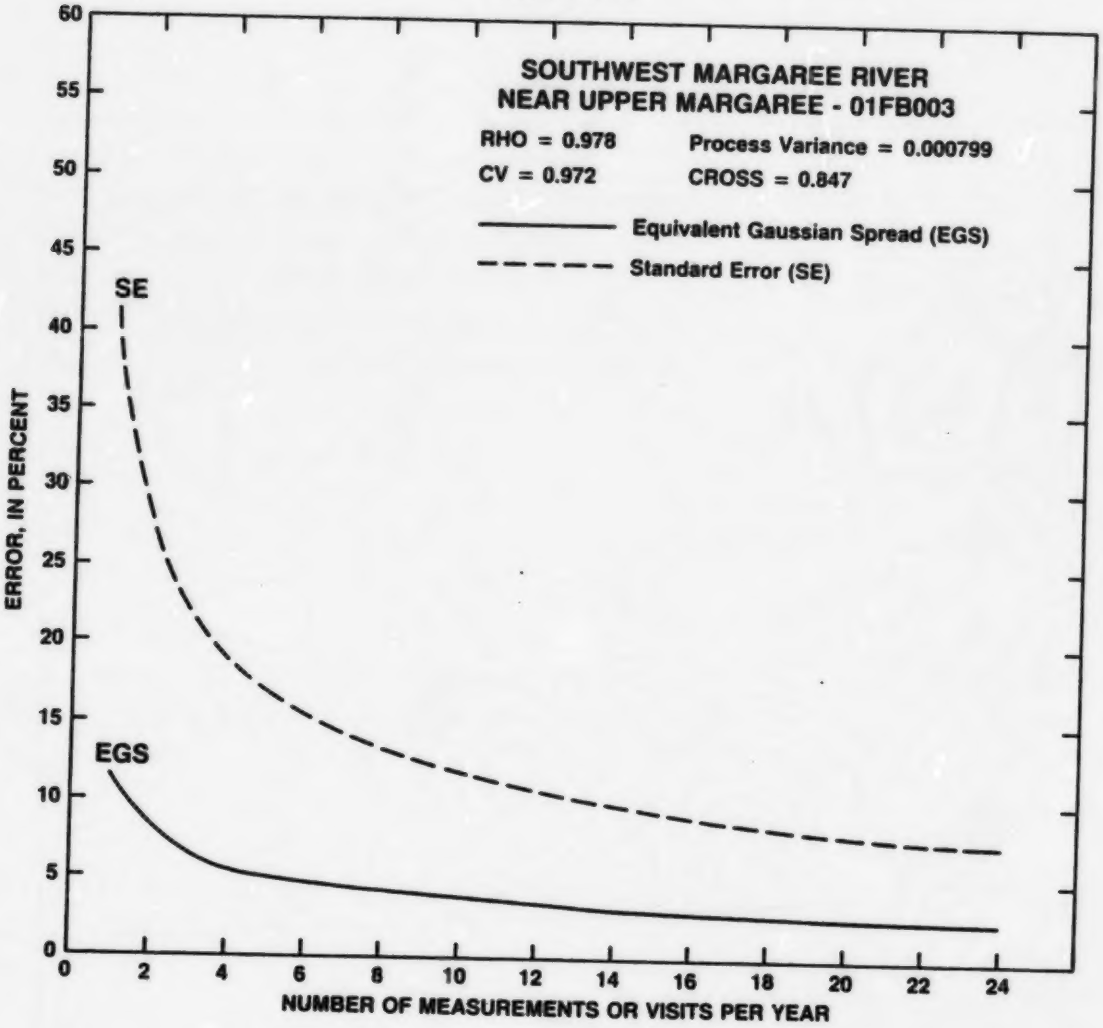

LISCOMB RIVER AT LISCOMB MILLS - 01EN002
RHO = 0.845
Process Variance = 0.001797
CV = 1.251
CROSS = 0.974
Equivalent Gaussian Spread (EGS)
Standard Error (SE)
SE
EGS
ERROR, IN PERCENT
0
5
10
15
20
25
30
35
40
45
50
55
60
0
2
4
6
8
10
12
14
16
18
20
22
24
NUMBER OF MEASUREMENTS OR VISITS PER YEAR

FIGURE 6.13


SOUTHWEST MARGAREE RIVER
NEAR UPPER MARGAREE - 01FB003
RHO = 0.978
Process Variance = 0.000799
CV = 0.972
CROSS = 0.847
Equivalent Gaussian Spread (EGS)
Standard Error (SE)
SE
EGS
ERROR, IN PERCENT
0
5
10
15
20
25
30
35
40
45
50
55
60
0
2
4
6
8
10
12
14
16
18
20
22
24
NUMBER OF MEASUREMENTS OR VISITS PER YEAR

assuming no errors in the measurements and no lost stage record. In other words, the process variance represents the error or uncertainty in estimating the discharge as a function of only the observed stage data. For example the process variance for station 01EH003 is 0.008359 squared logarithmic units. This converts to a standard error of 21.3 percent using the expression $(10^{2.303p}-1)^{0.5} * 100$ where p is the process variance from the above table. The 21.3 percent represents the error in the instantaneous discharge (two-thirds of the time) if the rating curve alone is used to compute instantaneous discharges. This assumes no measurements are used to update the rating curve and there is no lost stage record. The process variance for station 01EH003, East River at St. Margarets Bay, is the largest of the 5 stations analyzed. This results because this station frequently has low flows and has experienced zero flow. Rating curves are generally more unstable at low flows if the standard error is expressed in percent. As can be noted in Figure 6.6 for station 01EH003, the largest percentage deviations from the rating curve occur at low flows.

The standard errors for uncertainty functions computed without considering lost stage record can be interpreted as those errors occurring two-thirds of the time. However this is not true for the uncertainty functions considering lost stage record. Because errors in the estimated discharge arise from three different sources with widely varying precisions, the resultant distribution of those errors may differ significantly from a normal or lognormal distribution. This is why the parameter equivalent Gaussian spread (EGS) is introduced. The values of EGS are reported in units of percent and are briefly defined to be the errors in the instantaneous discharge occurring two-thirds of the time when lost stage record is considered in the computation of the uncertainty function. This parameter is defined further in the Appendix.

Uncertainty functions for both error criteria, standard error and equivalent Gaussian spread, are shown in figure 6.4 to 6.8 A few observations are pertinent:

1. The uncertainty functions without experted in EGS values are essentially unrelated to the number of measurements or visits per year for the three stations with low process variance, stations 01ED005, 01EN002 and 01FB003. For these stations the measurement standard error, which is assumed to be random in time, is a large part of the uncertainty function.
2. Station 01FB003 exhibits the largest difference between the two uncertainty functions. This is due to the low value of the cross correlation coefficient implying there is not a good nearby station for transferring information during periods of lost stage record.
3. Station 01EH003 exhibits the smallest difference between the two uncertainty functions. This is because of the high cross correlation coefficient.
4. The uncertainty functions expressed in standard error values are highest for the stations with the highest site variability (coefficient of variation), stations 01EH003 and 01EN002,because the variance during periods of lost stage record is larger for these stations.

The standard errors (SE) and EGS values for these uncertainty functions are summarized below for the 5 stations for various number of measurements or visits per year .

Station Number		Number of measurements or visits per year					
		1	3	5	10	20	30
		Errors expressed in percent					
01EC001	SE	36.7	18.1	13.1	8.6	5.9	4.8
	EGS	18.3	9.8	7.4	5.2	3.7	3.0
01ED005	SE	41.9	21.8	16.6	12.2	9.5	8.3
	EGS	13.5	9.1	8.4	7.7	7.0	6.5
01EH003	SE	53.2	25.7	18.6	12.2	8.2	6.6
	EGS	22.6	16.5	13.8	10.2	7.3	6.0
01EN002	SE	47.0	22.0	16.2	11.9	9.5	8.3
	EGS	14.8	10.8	10.1	9.3	8.3	7.5
01FB003	SE	41.7	22.3	16.8	11.6	8.1	6.6
	EGS	11.4	6.3	5.2	3.9	2.8	2.3

The standard errors and EGS values given in the above table illustrate the reduction in uncertainty of instantaneous discharge as additional measurements or visits are made to each station. The errors in the instantaneous discharge are essentially the same as the errors in daily mean discharge by virtue of the way the errors are computed. The error in the instantaneous discharge for a given measurement frequency is computed by averaging the errors of instantaneous discharge at 400 points in time between the discharge measurements. If 10 discharge measurements are made per year, it is assumed that these measurements are made at equal intervals throughout the year, i.e., 36.5 days apart. The error in the instantaneous discharge is determined by averaging the variances at 400 points in each 36.5 day period or about eleven times per day. Therefore the values shown in the above table are equivalent to the errors in the daily mean discharges.

Both the standard errors and EGS values in the above table are computed assuming a measurement is made on each visit to the station. This assumption is made for simplicity because there are numerous combinations of measurements and visits that could be investigated. Once the uncertainty function is computed and stored in a data file, the standard error or EGS value can be computed for any combination of visits and measurements. Furthermore the errors shown in the above table are for open-water conditions only. There was not a sufficient number of discharge measurements made during backwater conditions due to ice to develop uncertainty functions for this condition.

Since the EGS values represent the errors occurring two-thirds of the time, they will be used for illustration purposes. The EGS values for one measurement or visit per year range from 11.4 to 22.6 percent for the five stations. These errors can be approximately halved for all stations by making approximately 10 measurements or visits per year resulting in EGS values ranging from 3.9 to 10.2 percent. This reduction in uncertainty results because the increased visits reduce the incidence of lost stage record and the additional measurements increase the accuracy of the rating curve. The present visitation frequency for stations in the province is 10 times per year. If a measurement were made on each visit, then two-thirds of the time the instantaneous discharge would have an accuracy ranging from 3.9 to 10.2 percent for the five stations. One-third of the time the error would be higher than these values. There are no significant improvements in accuracy by making more than 10 measurements or visits per year. Ten visits per year ensure that minimal stage record is lost. Since the variance during periods of lost stage record is a major part of the total uncertainty function, little reduction in accuracy results by making more than 10 measurements or visits per year.

6.2.4 Uncertainty Function Conclusions

Through the use of Kalam-filtering techniques and regression analysis, a quantitative estimate of the error in instantaneous and daily mean discharge was obtained. This error was determined as a function of the number of discharge measurements or visits per year. This functional relationship between the accuracy of the data and the level of effort required to obtain these data is called an uncertainty function. The reader should keep in mind that the computation of the uncertainty functions is based on the assumptions that the time series of residuals is a first-order Markovian process and that regession analysis is a realistic method of transferring information during periods of lost stage record. These assumptions appear to be reasonable for streams in Nova Scotia. However, it is worthwhile to note that the errors given in the previous section are not necessarily the same as the errors of daily mean discharges published by the Water Resources Branch. They do represent the errors that would result if the Kalman-filter model was used to estimate daily mean discharges. If the Kalman-filter model is representative of the procudures presently used to compute daily mean discharges, then the errors presented earlier are equivalent to the accuracy of the published daily mean discharges.

The computation of uncertainty function provides managers and supervisors with useful information to effectively manage the stream gauging program. The individual uncertainty functions can be used to determine the accuracy of daily mean discharges at single stations as a function of the number of discharge measurements. To evaluate the cost-effectiveness of the entire stream gauging program, it is necessary to (1) compute uncertainty functions for all gauging stations in the program, (2) determine the costs of stations visits, (3) determine feasible routes for servicing the stations, (4) determine the costs of these routes and (5) determine overhead and computation costs associated with the program. All this information can be put to a computer program that determines the number of times each feasible route should be used in order to minimize the total uncertainty (variance) of all stations with respect to the operating budget. Fontaine and others (1984) describe such an analysis of the Maine stream gauging program. Hopefully a similar analysis can be undertaken for the stream gauging program in Nova Scotia.

6.3 Groundwater

Groundwater levels have been monitored in Nova Scotia since 1964. The N.S. Department of the Environment is responsible for maintaining the monitoring wells and equipment and the data base developed from the information collected.

A total of 50 wells have been monitored as indicated in Table 6.10; 31 of these are presently monitored as located in Appendix E-8 " Active (1983) Groundwater Monitoring Well Network and abandoned wells are shown in Appendix E-9. Sites, to date, have been established to satisfy the needs of particular projects or investigations, and their operation continued after those immediate needs were met.

Groundwater level fluctuations may be the result of various hydrologic phenomena, some natural and some induced by man. Fluctuations resulting from natural occurrences tend to be climate influenced and either short-lived, diurnal or seasonally effected. The "Lisse effect" (air entrapment in the vadose zone during groundwater recharge) and earthquakes produce short-lived fluctuations. Tidal influence, atmospheric pressure, and evapotranspiration result in diurnal changes, while groundwater recharge and bank-storage effects near streams correlate with seasonal variations. Fluctuations in association with man's activities i.e. groundwater pumpage, agricultural irrigation and drainage, and geotechnical drainage are primarily of a long term effect. Much of the information in this section was compiled by J. Robert McIntosh for "Groundwater Hydrographs in Nova Scotia 1965-81" (1984) and updated for use in this review.

TABLE 6.10

NOVA SCOTIA DEPARTMENT OF THE ENVIRONMENT'S OBSERVATION WELLS

STATION	COUNTY	WELL NUMBER
COLDBROOK	KINGS	001
TRURO	COLCHESTER	002
GREENWOOD	KINGS	003
FRASER BROOK	COLCHESTER	004
WILMOT	ANNAPOLIS	005
AMHERST	CUMBERLAND	006
MURRAY SIDING	COLCHESTER	007
GILLISDALE	INVERNESS	008
WOLFVILLE 1	KINGS	009
WOLFVILLE 2	KINGS	010
SHARPE BROOK	KINGS	011
WOLFVILLE 3	KINGS	012
TRURO 420	COLCHESTER	013
TRURO 421	COLCHESTER	014
TRURO	COLCHESTER	015
SABLE ISLAND 19	HALIFAX	016
SABLE ISLAND 50	HALIFAX	017
SABLE ISLAND 47	HALIFAX	018
MILL VILLAGE	QUEENS	020
WITTENBURG FARM	KINGS	021
LOWER CANARD	KINGS	022
THREE BROOKS 6	PICTOU	023
THREE BROOKS 5	PICTOU	024
THREE BROOKS 4	PICTOU	025
MONASTERY	ANTIGONISH	028
HAVRE BOUCHER	ANTIGONISH	029
POINT ACONI	CAPE BRETON	030
CANNING	KINGS	031
BERWICK	KINGS	032
SHEFFIELD MILLS	KINGS	033
OXFORD	CUMBERLAND	034
MURRAY SIDING	COLCHESTER	035
MURRAY SIDING	COLCHESTER	036
ANTIGONISH	ANTIGONISH	037
ANTIGONISH	ANTIGONISH	038
MUSQUODOBOIT HARBOUR	HALIFAX	039
MUSQUODOBOIT HARBOUR	HALIFAX	040
MUSQUODOBOIT HARBOUR	HALIFAX	041
SABLE ISLAND 17	HALIFAX	042
LAWRENCETOWN L3	HALIFAX	043
OAKFIELD PARK	HALIFAX	044
DURHAM	PICTOU	045
LAWRENCETOWN L1	HALIFAX	046
LAWRENCETOWN L2	HALIFAX	047
KENTVILLE INDUS. PARK	KINGS	048
NORTH SYDNEY	CAPE BRETON	049
SYDNEY	CAPE BRETON	050

6.3.1 Water Level Fluctuations Due to Precipitation

Precipitation that is not intercepted by vegetation, or collected into streams and surface water bodies, will percolate or seep into the soil. A portion of the water will be retained in the soil by a sponge-like effect referred to as the soil's field capacity. Water in excess of field capacity flows under gravitational influence, percolating down to the water table becoming part of groundwater. It eventually re-surfaces in springs, streams, rivers, lakes, and seas. On a world wide scale, the residence time of water in the ground has been estimated to range from two weeks to ten thousand years (Nace, 1971).

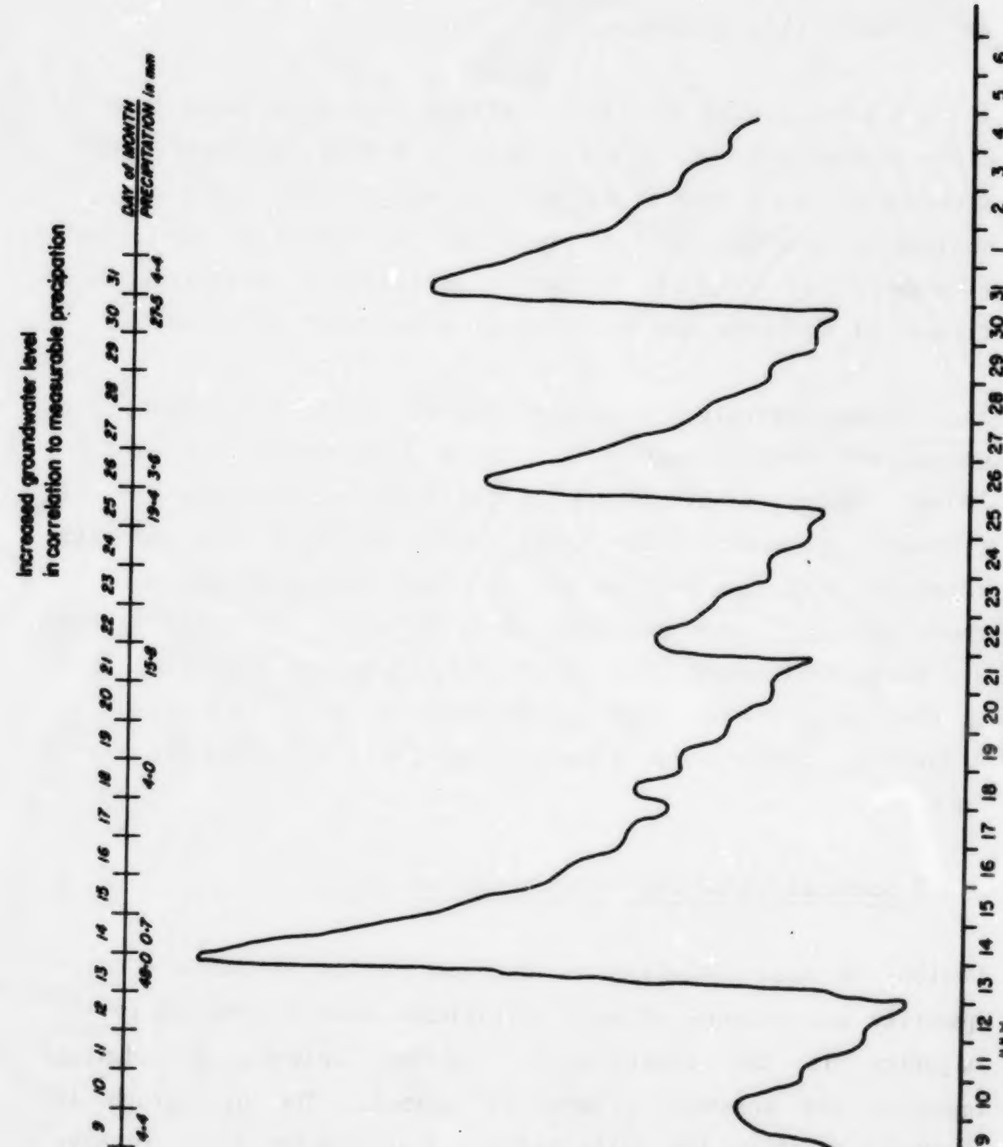
To be classified as a renewable resource groundwater must be continously replenished by recharge from precipitation. In Nova Scotia the surficial deposits and bedrock geologic units serve as both media and storage zone for the land-based portion of the hydrologic cycle. Precipitation data collected at Nova Scotia weather stations during a thirty year period shows the following mean annual total precipitations, Greenwood 1060 mm, Halifax 1381 mm, Sable Island 1270 mm, Sydney 1341 mm, Yarmouth 1283 mm (Hare and Thomas, 1974).

The hydrograph presented in Figure 6.14 represents a graphic record for the period July 7 to August 4, 1977 of the static water level in Observation Well 003. It illustrates the correlation of precipitation and increased groundwater levels. Dramatic increases in the water table level documented in Figure 6.4 are in conjunction with measurable precipitation recorded at Atmospheric Environment Station, C.F.B. Greenwood Nova Scotia.

6.3.2 Water Level Fluctuations Due to Tidal Influence

As with any maritime region the ocean influences the climate, the demography, and the economy. However one phenomenon not so

FIGURE 6.14



30 DAY PERIOD
1977
NOVA SCOTIA DEPARTMENT OF THE ENVIRONMENT
GROUNDWATER OBSERVATION WELL 003

readily realized is the diurnal fluctuation of groundwater levels in the freshwater/saltwater interface resultant from tidal changes. The hydrograph presented in Figure 6.15 is a salient example of the oscillatory effect upon coastal aquifers due to tidal fluctuations.

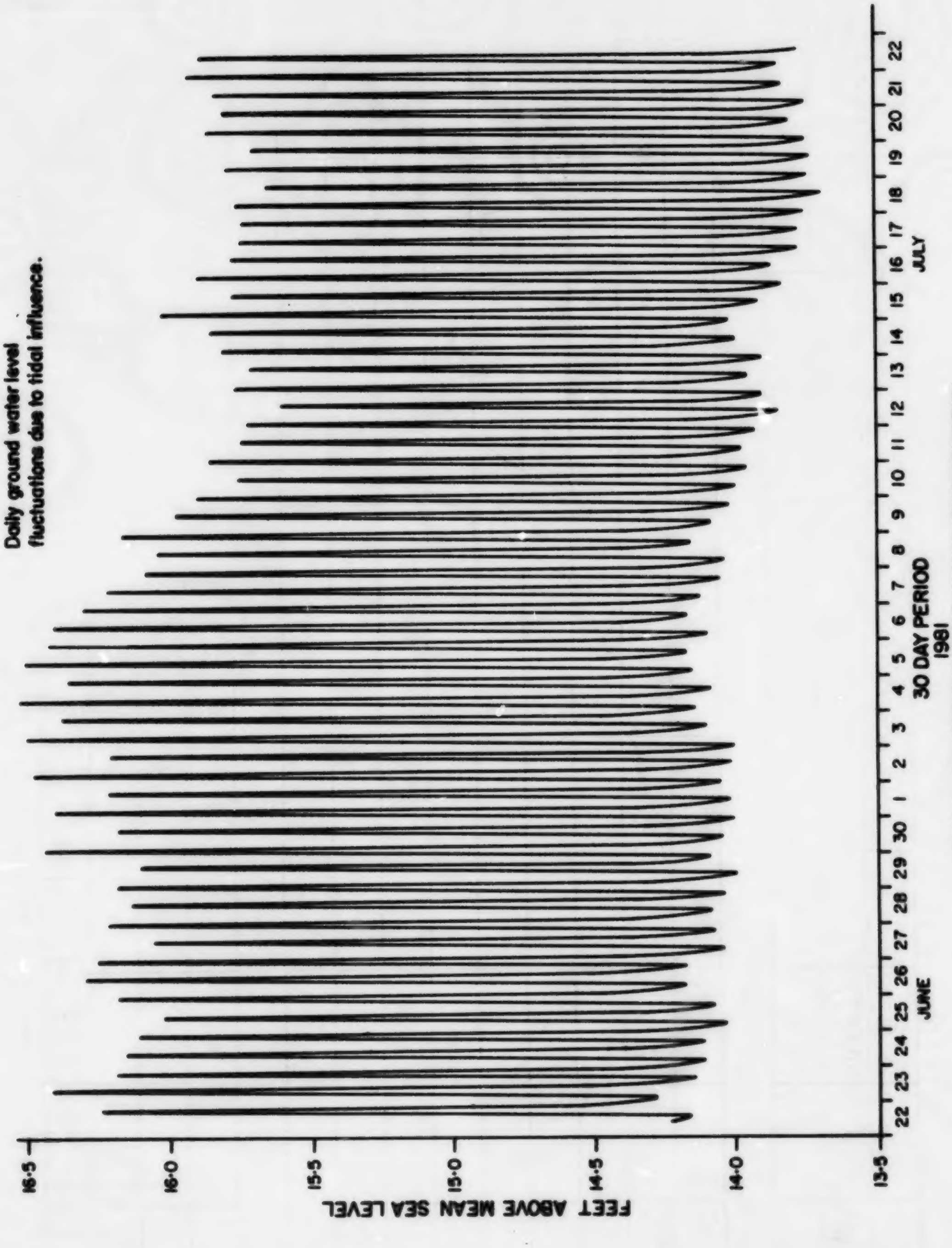
In Nova Scotia, with its vast coastline, and large population in close proximity to the ocean, there is a heavy dependence upon groundwater as a source for potable water along the coast. Monitoring coastal aquifers subjected to quantity removal of groundwater is essential to detect migration of saltwater into freshwater aquifers also referred to as seawater intrusion.

The Ghyben-Herzberg principle states that freshwater, in unconfined coastal aquifers, forms a lens which, due to its lesser density, floats on top of the seawater, analogous to oil floating on water. The lower limit of this lens or its interface with the seawater can be approximated by the rule of thumb that for every one foot of water above sea level, there are forty feet below. The potentially dangerous aspect of this is that for every one foot the static water level is lowered, in a coastal aquifer, the seawater interface is raised by forty feet.

6.3.3 Seasonal Variations of Groundwater Levels

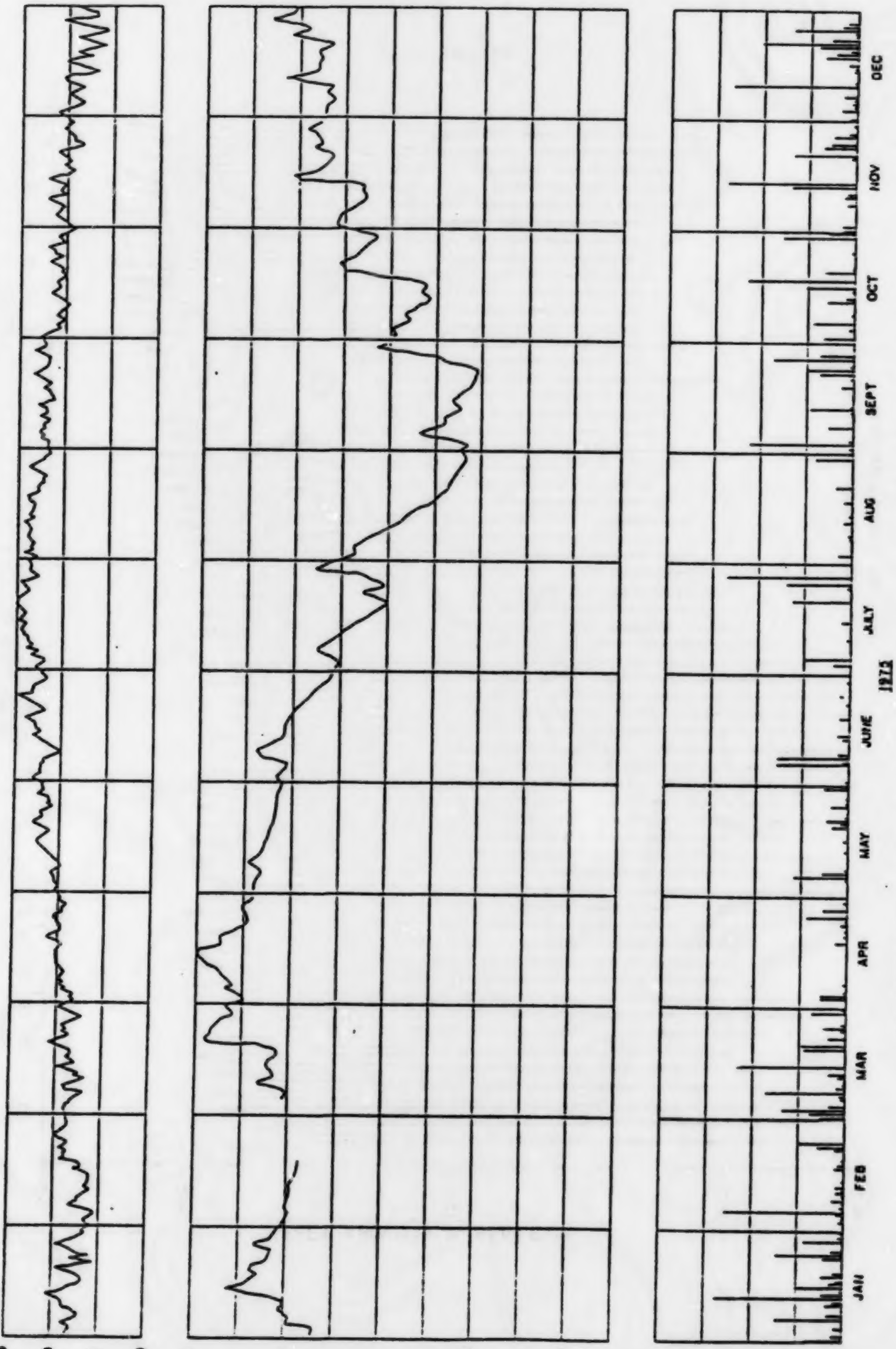
Obvious to most Canadians is the correlation of surface water quantity and seasonal climate variations, however unknown to the majority is the relationship existing between groundwater quantity and seasonal climate variations. The hydrograph in Figure 6.16 shows the daily average static water level in Nova Scotia Deparment of the Environment's observation well 003 for the year 1975. The hydrograph is representative of the water table contained in a sandy surficial deposit and may be expanded to include the general occurrence of groundwater in Nova Scotia.

FIGURE 6.15



NOVA SCOTIA DEPARTMENT OF THE ENVIRONMENT
GROUNDWATER OBSERVATION WELL 012

FIGURE 6.16



NOVA SCOTIA DEPARTMENT OF THE ENVIRONMENT GROUNDWATER OBSERVATION WELL 003

Data presented in Figure 6.16 indicate that the water table level varied by approximately three feet in 1975. The recorded high occurred during the month of April when the daily mean temperatures remained above the freezing point and resulted in the melting of the accumulated snow. The lower water table levels appear during the later months of summer and are the result of several factors; decreased precipitation and increased vegetation interception of precipitation, transpiration and evaporation.

6.3.4 Water Level Fluctuations Due to Water Removal From an Aquifer.

Water removal from an aquifer via a well results in the lowering of the water level in the well and the surrounding hydrostratigraphic unit. A drop in well water levels as a result of pumping is referred to as drawdown. The degree of drawdown is dependent upon the hydraulic characteristics of the aquifer and is an important factor in calculating the well's potential yield.

The hydrograph presented in Figure 6.17 illustrates the drawdown in a sand and gravel aquifer resulting from the removal of a quantity of water at the rate of 320 U.S. gal/min. by the pumping of a municipal water supply well 275 feet away. Also documented in Figure 6.17 is the rapid rise in the water level, the "recovery" of the well, as a result of the cessation of pumping. The rate of recovery is also an important factor in the analysis of the aquifer's hydraulics.

6.3.5 Monitoring Well Hydrographs and Summary Tables

Monitoring wells, having 5 years of record or more, have had the data summarized in tables and in graphic form. These hydrographs and tables are presented in Figures 6.18 and Table 6.11, as well as, in Appendix B, and show the well lithology,

FIGURE 6.17

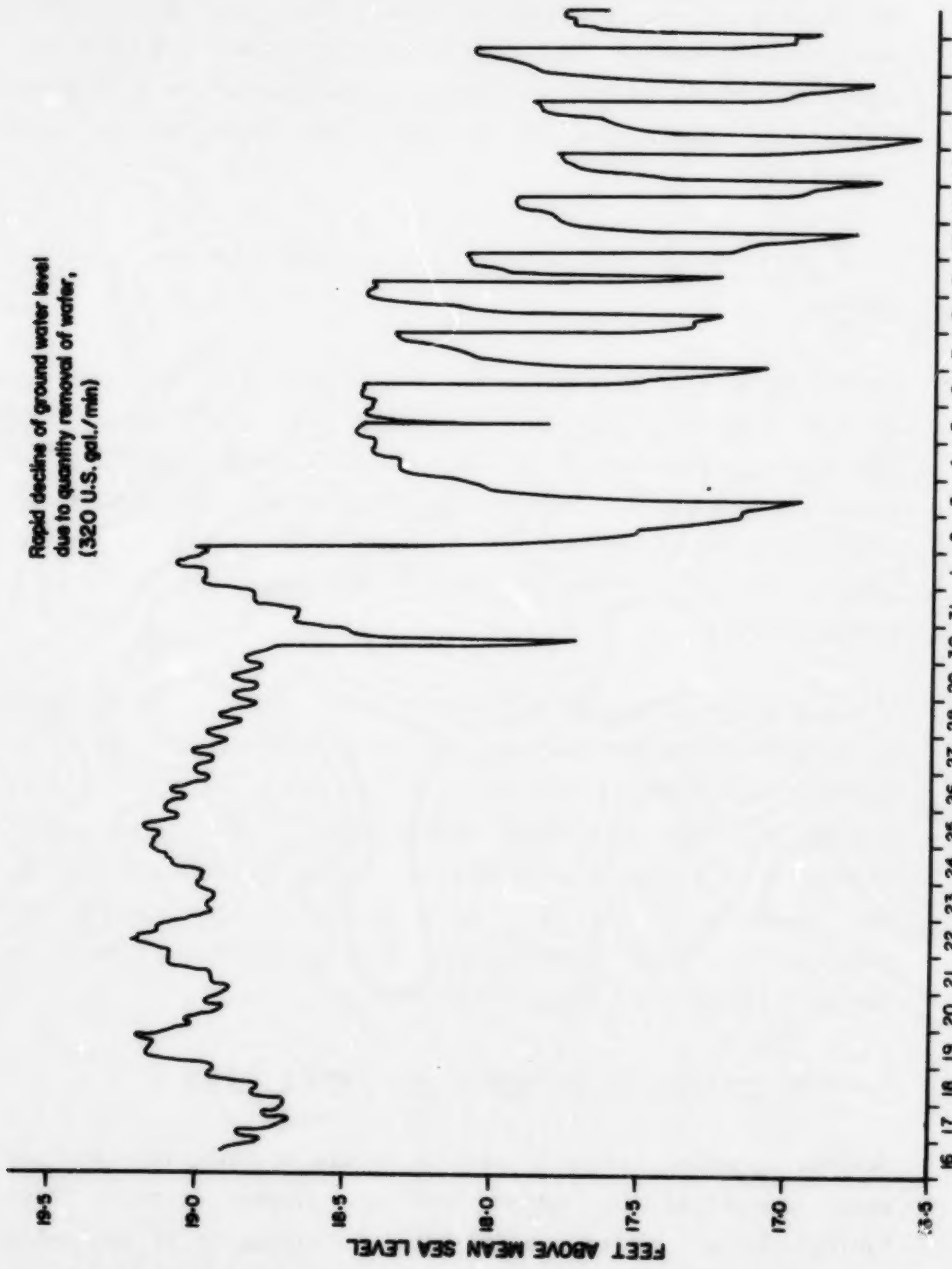
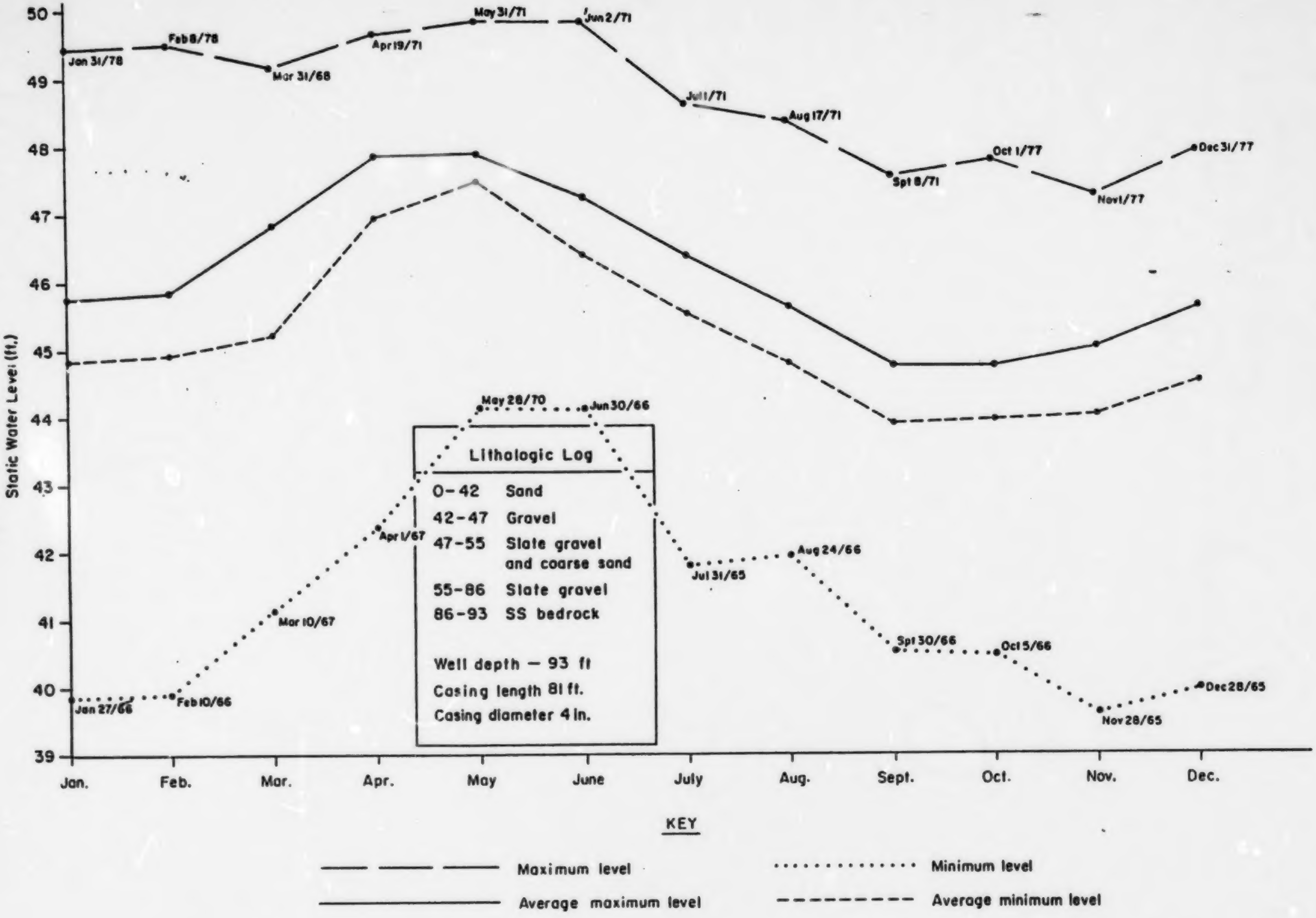

Rapid decline of ground water level due to quantity removal of water, (320 U.S. gal./min)
FEET ABOVE MEAN SEA LEVEL
19·5
19·0
18·5
18·0
17·5
17·0
16·5
16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
MAY
JUNE
30 DAY PERIOD
1980
NOVA SCOTIA DEPARTMENT OF THE ENVIRONMENT
GROUNDWATER OBSERVATION WELL 009

FIGURE 6.18



COLDBROOK—N.S.D.O.E. OBSERVATION WELL 001, FEBRUARY 1965—1983

TABLE 6.11

COLDBROOK N.S.D.O.E. OBSERVATION WELL 001 FEBRUARY 1965-1983

STATIC WATER LEVEL READINGS IN FEET ABOVE SEA LEVEL

	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
AV. MAX. LEVEL	45.77	45.87	46.87	47.91	47.94	47.31	46.44	45.65	44.80	44.80	45.07	45.65
AV. MIN. LEVEL	44.86	44.93	45.25	46.99	47.53	46.45	45.58	44.82	43.92	44.00	44.05	44.54
MAX. LEVEL	49.48	49.52	49.18	49.70	49.90	49.88	48.65	48.40	47.58	47.82	47.32	47.98
MIN. LEVEL	39.87	39.90	41.13	42.38	44.15	44.15	41.83	41.95	40.53	40.48	39.62	40.00
Dates												
MAX. LEVEL	31/78	8/78	31/68	19/71	31/71	2/71	1/71	17/71	8/71	1/77	1/77	31/77
MIN. LEVEL	27/66	10/66	10/67	1/67	28/70	30/66	31/65	29/66	30/66	5/66	28/65	28/65

average maximum and minimum water levels on a 12-month basis average over the total period of record, and the monthly absolute maximum and minimum water levels on a 12-month basis with their respective dates.

The information from these hydrographs and tables indicates an envelope of fluctuation within which the water level, in the particular aquifer monitored, may normally be expected to be found. Also shown are the seasonal changes this envelope will normally experience in the year.

Trends, indicating either a general raising or lowering of the water table in these aquifers, are not evident from this information.

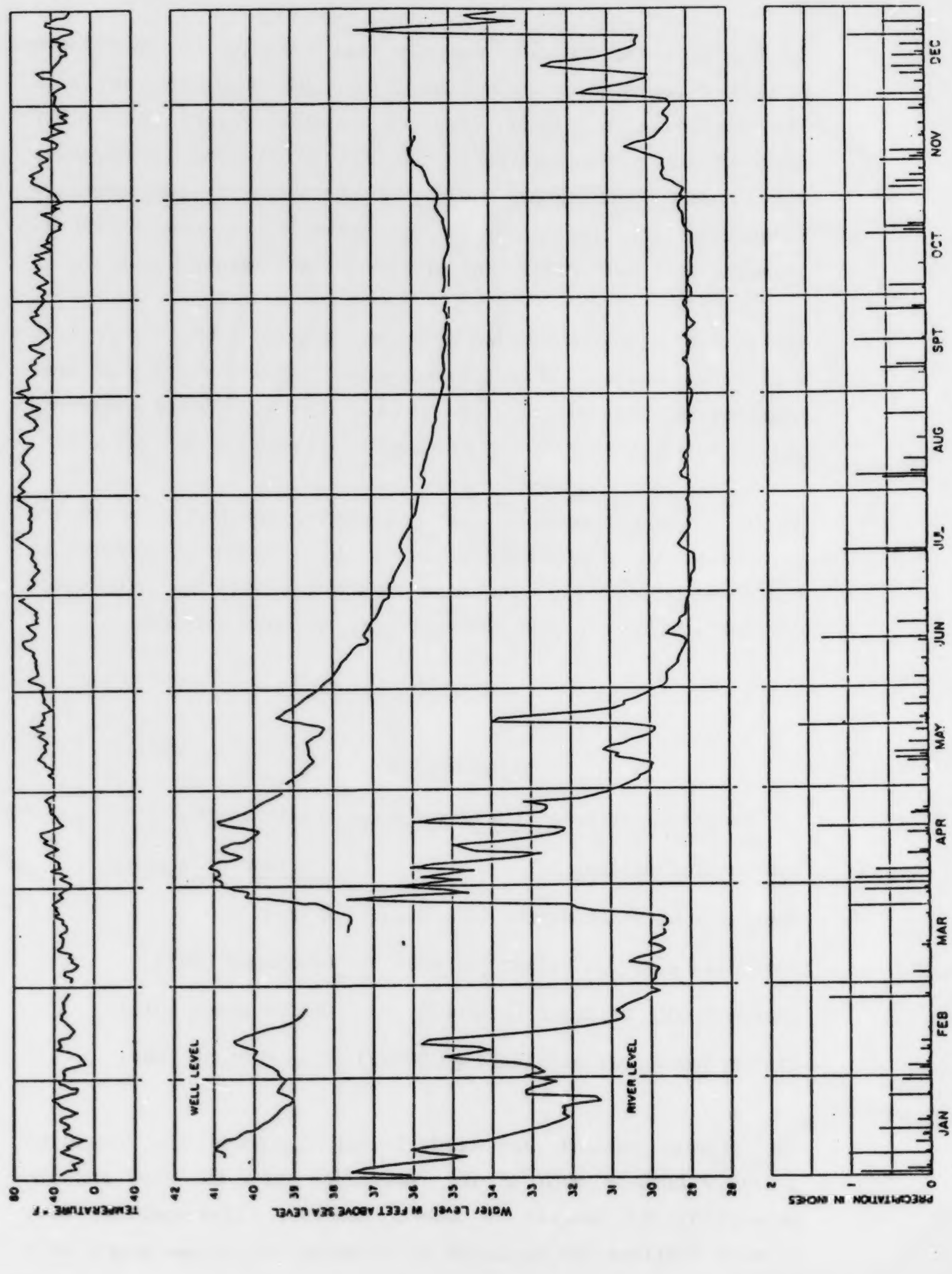
6.3.6 Interaction of Groundwater,Surface Water and Precipitation

Figure 6.19 shows the correlation between temperature, groundwater level, surface water stage, and precipitation, all measured at site in the same drainage basin and in relative close proximity to each other; approximately seventy-five metres between the surface water and groundwater sites. Particular features which are readily noticeable here are: the slow response of groundwater in late March and early April caused by the low temperatures and probability of frost in the ground at that time; base flow in the river during the summer months is almost entirely drawn from and depleting groundwater; rain events, occurring while groundwater is low, have a greater effect as groundwater recharge than as surface runoff, noticed particularly here at the latter half of October.

The collection of these types of data, simultaneously, on the various components of the hydrologic cycle, and by continuous recording, is particularly useful in developing comprehensive basin analyses.

FIGURE 6.19

TEMPERATURE, GROUNDWATER, SURFACE WATER AND PRECIPITATION RELATIONSHIP: ANNAPOLIS RIVER BASIN TO WILMOT (1969).



6.4 RELATIONSHIP OF SURFACE AND GROUNDWATER NETWORKS TO OTHER NETWORKS

In the past the various networks that make up the hydrologic network were established by the responsible agencies, and with the exception of joint projects, little regard for other networks was given. While it has not yet become commonplace, the various agencies are talking of establishing complementary networks as the opportunity arises. This is not an easy task as it means that some monitoring sites must be abandoned or moved.

Water quality and suspended sediment samples were collected by different branches of the Inland Waters Directorate at or near Hydrometric Stations. These tasks are now being perfomed successfully by Water Suvey of Canada Division field staff.

At the present time only four groundwater monitoring wells are located within a watershed monitored by a hydrometric gauge as shown in Table 6.12. The main reason for this is groundwater network station are, for the most part, project stations.

TABLE 6.12

Gauged Watersheds with Groundwater Monitoring Wells

Hydrometric Station	Groundwater Station
Annapolis River at Wilmot (01DC005)	Wilmot (005)
Annapolis River at Wilmot (01DC005)	Greenwood (003)
Sharpe Brook at Lloyds (01DC004)	Sharpe Brook (011)
Fraser Brook near Archibald (01DH003)	Fraser Brook (004)

The climate network has traditionally followed the shoreline possibly because much of the population does the same and the network relies heavily on manual readers. Consequently, many climate stations are situated at or below the stream gauge. Only

12 of the 88 climate stations are located within the watershed monitored by a hydrometric station as listed in Table 6.13 and shown in Appendix E-13 "Active (1983) Hydrometric and Climatolocial Stations".

It must be remembered that the present technology used in collecting climate data generally requires daily readings by daily attention. For the most part the interior of watersheds are remote, and suitable sites may not occur in the natural state. Efforts should be expended to find locations that can be used with the present technology.

Real time data are generally required at locations where regulation of the streamflow is critical or flood forecasting of downstream locations is required. In Nova Scotia real time data are provided through a satellite data collection platform (DCP). In 1983 only two such stations existed. The first DCP is located at Cheticamp River below Artemise Brook - 01FC003 and provides information used to monitor the maintenance low flows required from the Wreck Cove diversion of Cheticamp Lake.

The other DCP is located on the Mersey River at the Kejimkujik National Park Administration Building, it relays water quality parameters, such as pH, conductivity, water temperature and dissolved oxygen to monitor any acid shock from runoff. During the 1984-85 period three additional streamflow DCP's will be added, one each at;

a) Mersey River below Lake George (01ED007);
b) Kelley River at Eight Mile Ford (01DL001);
c) Northeast Margaree River at Margaree Forks (01FB003).

These were selected basically for their remote location and the cost saving that could be realized by less station visits.

Table 6.13 - Gauged Watersheds with Climate Stations

Hydrometric Station	Climate Station
01DC005 - Annapolis River at Wilmot	Greenwood A
01DC005 - Annapolis River at Wilmot	Aylesford CDA
01DC007 - Annapolis River at Lawrencetown	Greenwood A
01EA007 - Annapolis River at Lawrencetown	Aylesford CDA
01EA003 - Tusket River at Wilson's Bridge	Kemptville
01ED005 - Mersey River below Lake George	Kejimkujik Park
01EE001 - Medway River at Charleston	Harmony
01EF001 - LaHave River at West Northfield	Springfield
01EF001 - LaHave River at West Northfield	Farmington
01EK001 - Musquodoboit River at Crawford Falls	Middle Musquodoboit
01FV003 - Southwest Brook near College of Cape Breton	Sydney A

It may be noted that with the exception of the Mersey River, LaHave River and Southwest Brook, the above watersheds have regulated flow at the hydrometric gauge, thus making them less useful for direct analyses of rainfall/runoff events.

CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

7.1 CONCLUSIONS ON NETWORK COVERAGE AND DATA ANALYSES

7.1.1 GENERAL

Results of the users survey indicate that the data collected from the surface water and groundwater networks serve many uses for a variety of industries, consultants and government agencies. The annual dollar value of the programs using hydrologic data, not including the operations of the networks, is $550 million for electric power generation, and $128 million for other concerns. This is a total of $678 million annually. The need for continuing these forms of data collection, recording and reporting is confirmed considering that A) this amount is the total spent by less than half of the users who responded to the survey, B) 70% of the interests surveyed are of a continuous, or ongoing nature, and C) nearly 60% of the interests surveyed are at least 25% dependent on having hydrologic data and 25% are totally dependent on these data.

Many cases of lack of knowledge and misconceptions about the hydrologic networks became evident during the users survey. It is important to develop a public relations and marketing plan of making people aware of the availability of the information that exists, where to find the data, and how to use it.

The extent of the water quality monitoring network is small for both surface and groundwater.

7.1.2 Surface Water Network

A) Statistics on the mean annual discharge from the long term hydrometric stations showed, that from the existing data base of large rivers, the province could be divided into three areas, each containing stations portraying similar statistical characteristics.

The three areas, as previously identified by Ingledow (1970) as hydrologic zones, are:

2B - Southwest Nova Scotia
2C - Northeast Nova Scotia
3 - Cape Breton Highlands

B) Correlations between stations using monthly mean data showed that the poorest fit occurs during low flow periods. It is during this time that the geology of the basin becomes the major influence on the streamflow characteristics. Low flow is therefore harder to predict for ungauged areas. However, this information, is essential to the economic development of water supplies for residential, commercial and industrial uses.

C) From Appenxix E-12 it is noted that of the 88 climate stations, nine are located in the upper reaches of seven river basins, which are monitored by a hydrometric gauge. Five of the seven rivers are regulated. Twelve climate stations are located within five kilometres of the hydrometric gauges. Six of these stations are on regulated streams. It is also noted that seven of the eleven regulated flow watersheds monitored by a hydrometric gauge have at least one climate station near the hydrometric gauge or in the upper reaches and five of these meet the WMO two climate stations per hydrometric station criteria. In comparison only one natural flow hydrometric station has a watershed with two climate stations.

D) The quality of the discharge record for a specific station is only available in subjective terms. The methods of computing uncertainty functions as described in Section 6.1.7 provide a sound technique for quantifying the accuracy of the data. The method also provides information on the pay back in terms of resulting accuracy from the streamflow velocity measurements completed during station visits.

E) Correlation analyses were performed between the long term stations and the short term stations with at least 15 years of data. From these analyses two station pairs showed good correlation with long term stations using annual and monthly mean data. The two stations having good correlations with a long term station are: 01EN002 - Liscomb River at Liscomb Mills and 01EG002 Gold River at Mosher's Falls.

Correlation analyses also showed that drainage area was less a factor in correlation between stations than was location or zone physiography. Adjacent stations with different drainage areas were closely correlated while adjacent stations of similar size but with different physiography did not necessarily correlate well.

F) Various statistical analyses such as low flow and flood flow frequencies, statistics on mean monthly and mean annual discharge, and correlation analyses were performed on the data from the network. Generally the analyses showed that the hydrology of Nova Scotia is diversified and little redundancy in current coverage could be identified. The analyses used, allowed for the grouping of stations into zones in which stations would show similar statistical parameters.

G) By comparing the hydrometric, precipitation and groundwater networks it was readily apparent that there is little coordination among the three networks. W.M.O. network standards maintain that a gauged watershed should contain at least two precipitation gauges to provide adequate information for estimating missing records and for the development of techniques for estimating runoff from ungauged areas. The number of watersheds which presently contain precipitation gauges is insufficient.

H) Each data user has a general and often a specific need for data in the currently published form as well as in a more interpretated form, such as, regional analyses or trans basin studies. Often the user and WRB suffer from tunnel vision in terms of data requirements and it is difficult to determine beforehand what activities would provide the greatest benefit.

I) Of the fifty-three active stations in the network, only twenty-nine are categorized as "Water Quantity Inventory Stations" under the cost-sharing agreement. The remaining twenty-four stations were established for special projects or to fulfill requirements and obligations under various federal and provincial programs. These stations may be active for short periods (one to five years) or they may monitor a highly regulated stream.

J) Nova Scotia has many rivers which drain highland and lowland watersheds. In some cases, hydrometric stations have been located to measure the total discharge from these physiographically different areas. While providing valuable information on the larger watershed the individual basin responses are masked in the compound flow data. This fact makes the station data less discrete and limited in its use in regional studies and consequently less is understood about the resource. With additional stations located on one or more of the tributaries, the characteristics of the individual sub-basins can be separated. Intra-basin relationships can be developed along with more representative parametric models between river basins.

K) In examining the National and Regional Inventory Hydrometric Gauging Stations, the proportion of small, medium and large watersheds are similar between the Hydrologic Zones 2B and 2C. There are clusters of small and medium stations around the Sackville area of Zone 2B and of medium sized stations around the Salmon River above Truro area of Zone 2C. There are three inventory stations in Zone 3 and of these two are of similar size, although the physiographic characteristics of these similar sized watersheds are dramatically different.

L) An increase in mean annual runoff (2%-15%) has been detected in the last 15 years in relation to the mean annual runoff over the past 65 years. This could be due to an increase in annual precipitation, a change in the seasonal timing of the precipitation, changes in basins or changes in the quality of the data.

M) Four of the National and Regional Inventory Hydrometric gauging stations are designated as monitoring regulated flow. The degree of their regulation has not been determined, thus their usefulness as Inventory stations is in question.

There is a need for wider dispersion of smaller gauged basins in Zone 2B; a more even dispersion of all stations in Zone 2C; and more smaller drainage area stations in Zone 3. These smaller watersheds are typically the source of supply for municipalities and industries.

N) During the analyses of the runoff data, very little information on runoff near the coast was available. However, that is where many of the precipitation stations are established. In order to provide information on the runoff pattern along the coast, stations with small drainage areas should be selected to determine the runoff characteristics of coastal streams.

O) Awareness of flood hazards has increased in recent years as a result of the efforts expended under the cost-shared Canada-Nova Scotia Flood Damage Reduction Program. Little knowledge is available in areas where man's activities in the flood plain have not been interfered with by high water levels. These data may be of use to municipal governments and may be provided as part of a self help program whereby a staff and crest gauge is installed with the agreement that the municipality takes responsibility to check, read and record the stage on a predetermined schedule. The data would be entered in a miscellaneous data file and retrievable in a systematic manner.

P) During the maintenance of the hydrometric station inventory index file, (HYDEX), errors were made concerning the start of regulation of the flows in a watershed and the subsequent change in drainage area. The Reference Index and the Historical Streamflow Summary for stations Indian Brook at Indian Brook (01FF002) and Cheticamp River above Robert Brook (01FC002), show the drainage area of the basins after the diversions were made for the Wreck Cove Hydro Project. No reference was made to the change in drainage area as a result of the regulation. Consequently, these stations which are draining significantly changed drainage areas or, in the case of Cheticamp River where spills are made to the natural watershed, the drainage area is varying in size.

Q) It was demonstrated that efficiencies in the field operation can be realized through the use of the "Uncertainty Function" - to predict the payback from the number of station visits versus the expected errors in the stage discharge relationship.

7.1.3 Groundwater Network

A) Appendices E-8 "Active (1983) Groundwater Monitoring Well Network" and E-9 "Abandoned Groundwater Monitoring Well Network" indicate the locations of present and discontinued groundwater observation well sites. Also indicated are void areas with no observation well sites. These areas occur in most of the Eastern Shore, all of the South Shore, all of the Southwestern Area, and much of Cape Breton. Many of the more heavily populated sections of the province are included in these areas along with much of the fishing industry. Local shortages of water and the increasing demands for it, particularly for fishing operations, has been identified, for example, in "Regional Water Resources Southwestern Nova Scotia" R. Porter (1982). It is necessary to provide coverage of these unmonitored areas as well, to assure adequate coverage in hydrostrategraphic units.

B) The comparison of the groundwater, surface water, precipitation and temperature data over the same time, shown in Section 6.3, demonstrates the close and delicate interaction of these elements in Nova Scotia. The availability of these data permits good insight into local conditions with respect to the water resource and an overview of the drainage basin.

C) No groundwater quality monitoring network is in place at this time, although it is planned to commence operation, in conjunction with the present groundwater level monitoring network, in 1985.

D) Current methods of data storage made the task of updating groundwater analyses both time consuming and costly. In addition to this, it was difficult to perform meaningful statistical analyses on these data.

7.2 RECOMMENDATIONS

7.2.1 General

The recommendations have been organized to relate directly, according to their lettered identification, with the foregoing conclusions.

In view of the dollar value of projects using hydrologic information and the ongoing need it is recommended that the existing level of monitoring be maintained and, more comprehensive coverage be effected in areas found to be lacking in specific types of coverage, i.e. small coastal streams which are typically the source of water supply for municipalities and industry.

It is further recommended that marketing measures be utilized to inform potential users of this information that the data are available, and accessible.

In overall terms, it is further recommended that a more unified approach be taken towards the monitoring and recording of Nova Scotia water resources. The agencies currently involved, the Atmospheric Environment Service, Environment Canada, Nova Scotia Department of the Environment, and Inland Waters Directorate, Environment Canada should discuss, at least once per year, their respective plans prior to implementation. The probability for a more co-ordinated coverage of the various phases of the hydrologic cycle as it occurs in Nova Scotia should be greatly increased.

It is reommended that more extensive water quality monitoring networks be established to povide a more comprehensive overall understanding of this aspect of the resource throughout Nova Scotia.

7.2.2 Surface Water Network

A) It is recommended that the apportionment of the long term stations be divided among the three zones, 2B, 2C, and 3. Each zone should have coverage based on watershed size and physiographic characteristics.

B) It is recommended that low-flow partial record stations be established in presently ungauged areas to measure streamflow during the normal low flow period, which is typically mid-summer to mid-fall. These stations should be co-located in watersheds which are monitored by stations of the groundwater observation well monitoring network.

C) It is recommended that common network plans be discussed with Atmospheric Environment Service to increase the number of climate stations in gauged natural flow watersheds especially in the river basins monitored as national and regional water quantity inventory stations.

D) It is recommended that a full analysis of the entire stream gauging program be performed. New techniques, for evaluating the cost effectiveness of data collection programs have been developed. These techniques, being applied by the United States Geological Survey, will identify strategies for operating the stream gauging program so that uncertainty is minimized in proportion to the program funding level. As a first step in this exercise it is recommended that uncertainty functions be computed for all active stations with a minimum of fifty streamflow measurements. This information should then be used to optimize the Water Survey of Canada stream gauge operation field program.

E) It is recommended that the financial impacts of relocating equipment presently used at the two stations which correlate closely with other existing stations be investigated. A study to produce a way of estimating annual and monthly flows is to be done prior to relocating stations.

F) It is recommended that further study be undertaken to develop a better understanding of relationships between stations within a hydrologic zone. Ultimately it is desirable to identify parameters that will explain most of the variance but are relatively simple to determine and easy to define. For example, generalized least squares regression methods (Thomas et al, 1985) should be used to aid the decision process of adding or deleting stations from the network.

G) It is recommended that WMO standards be adopted as guidelines for the establishment of these networks in Nova Scotia and that steps be taken to meet these standards.

H) It is recommended that a data users' seminar be held which would incorporate such data suppliers as AES, NSDOE, and IWD (WRB & WQB) and the user community. Discussions could bring forward useful information on needs as well as inform the users of what presently can be provided as well as what is planned for the future.

I) It is recommended that the areas shown in the 1967, 1970 and 1984 network reviews as being unrepresented, be the first priority for network expansion or relocation in the 86/87 discussions on cost sharing. While the network expanded from 36 hydrometric stations in 1967 to 53 in 1984 none of the recommended stations have been established nor could any reports be located describing the process, if any, that was followed in not establishing any of these stations. It is further recommended that any future reconnaisance for possible hydrometric gauging sites be reported upon, describing and showing the locations considered and the reason for rejection or acceptance.

J) It is recommended that river basins be studied to identify hydrometric stations which monitor the stream discharge below the confluence of streams from two or more distinctly physically different watersheds. Areas of interest should include the Cobequid Uplands, Pictou-Antigonish Highlands and the Cape Breton Uplands. Hydrometric stations should be established on one or more of the tributaries of the identified streams. These stations should be maintained until satisfactory relationships can be developed between the intra-basin stations as well as with other basins in the hydrologic zone.

K) It is recommended, 1) that a greater number of smaller drainage area watersheds be monitored throughout the southern and western portion of zone 2B; 2) that stations be established to monitor small and/or medium sized basins in the western portion of zone 2C; and 3) that additional stations monitoring small drainage areas be established in zone 3.

L) It is recommended that a study be conducted to determine the cause for the general increase in the runoff in the province since 1969.

M) It is recommended that long term regulated streams classified under National and Regional Inventory category be analyzed and the degree of regulation determined. If the station is found to be highly regulated, to the point where it adds little information to regional hydrology, it is recommended that such stations be reclassified apart from the inventory category or discontinued, subject to confirming what client needs are.

N) It is recommended that hydrometric stations monitoring small watersheds near the coast be selected for inclusion in the network.

O) It is recommended that an investigation be conducted to determine the need for a sub-network of manual and/or crest gauge stations to be installed by WSC but read by the data user. Typical users would be municipal governments, provincial departments, conservation or residents associations.

P) It is recommended that any change in the contributing drainage area be printed in the Water Resources Branch publications such as the Historical Streamflow Summary and the Reference Index, and/or that the station number be changed at the effective date of the alteration as the data before and after this date are from statistically different populations.

Q) It is recommended that a cost effectiveness analysis of the entire stream gauging program be performed. New techniques, for evaluating the cost effectiveness of data collection programs have been developed. These techniques, now being applied by the United States Geological Survey, will identify strategies for operating the stream gauging program so that uncertainty is minimized in proportion to the program funding level.

7.2.3 Groundwater Network

A) It is recommended that groundwater monitoring sites be established in areas such as Southwestern Nova Scotia, the South Shore, the Eastern Shore, Cape Breton, and the Western portion of the Cumberland Basin, where demands for groundwater supplies exist. Further to this, in cases where low yield bedrock is encountered, that observation wells be constructed in the surficial material to monitor bedrock and surficial aquifers.

B) It is recommended that new groundwater monitoring sites be established as close as possible to surface water monitoring sites to permit monitoring the interaction between these resources as well as monitoring the individual resources and supporting multidisciplinary studies.

C) It is recommended that a groundwater quality monitoring network be established and maintained.

D) It is recommended that the method used for handling groundwater data be improved using existing technology to allow for rapid handling and retrieval, thus enhancing the level of service to potential and actual data users.

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APPENDIX A

1984

QUESTIONNAIRE

HYDROLOGIC NETWORK ASSESSMENT FOR NOVA SCOTIA

NAME OF AGENCY: ______________________________

ADDRESS: ______________________________

____

Contact and position ______________________________

______________(phone number)______________

NOTES: (i) Please check one or more answers for each question, as appropriate. If necessary use the reverse side of these pages for extra space.

(ii) See the attached maps for Nova Scotia:
Please use Map "A" for present area(s) of concern.
and Map "B" for expected future areas(s) of concern.

1. Locations Where Data are Required: Please indicate as precisely as possible on the maps provided the locations in Nova Scotia where your agency needs hydrologic data. Also, indicate new locations for which data may be required.

i. Total number of Stations used: ______________________

ii. Do you require Province wide station coverage: Yes ___ No ___

If NO a) Name of Stream: ______________________

b) Name of Lake or Water Body: ______________________

2. Type of Data Required:

i. Water Level: ____________

ii. Discharge: ____________

iii. Flow velocity: ____________

iv. Ice thickness ____________

v. Groundwater levels ____________

vi. Temperature ____________

vii. Other: (Specify) ______________________________

3. Please indicate, by checks in the appropriate columns, any of the following project types for which your authority has used hydrologic data over the past five years. The column headings indicate the purposes for which the data have been used as follows: Investigation (I), Design (D), Construction (C), and Operation (O).

	I	D	C	O
i. - Hydroelectric power				
ii. - Withdrawals for industrial use				
Withdrawals for municipal and residential use				
Withdrawals for irrigation use				
iii. - Navigation				
iv. - Flood mitigation using storage				
v. - Flood forecasting				
vi. - Storm-water drainage				
vii. - Bridge design				
vii. - Low-flow augmentation				
viii. - Water quality assessment				
ix. - Monitoring effects of waste disposal				
x. - Water management and apportionment				
xi. - Recreation				
xii. - Planning and resource evaluation				
xiii. - Investigation and/or research				
xiv. - Other (please specify)				

4. Please indicate which of the above project types your authority has been most involved with by placing a circle around each appropriate check mark.

5. Time Period Coverage:

i. Monthly Summary: ____________ ii. Annual Summary: ____________

iii. Other (Specify): ______________________________

6. Format of Data Required:

i. Preliminary tabular format: ___ iii. Microfiche: ____________

ii. Annual Publication: __________ iv. Computer Tapes: ____________

v. Other (Specify): ______________________________

7. Frequency of Data Required:

i. Hourly: ______________ iii. Monthly: ____________

ii. Daily: ______________ iv. Yearly: ____________

v. Other (Specify): ______________________________

8. Projected Period of Data Required: Please indicate to which stations this requirement applies.

i. Continuous: ____________ iii. Up to 1990: ____________

ii. Up to 1985: ____________

iv. Other (Specify) ______________________________

9. Dependency of Your Program on Hydrologic Data:

i. Totally dependent (100%): ____ iii. 25%: ______________

ii. 50%: ______________

iv. Other (Specify): ______________________________

10. Which type(s) of analysis(es) are you interested in:

Surface Water:
(a) _____ Annual Mean, Sd and Cv
(b) _____ Monthly Mean, Sd and Cv
(c) _____ Daily Mean & Population Skew. vs. statistics of extremes
(d) _____ Duration analysis, flow vs. percent time exceeded daily
(e) _____ Low flow frequency
(f) _____ High flow frequency
(g) _____ High flow vs. drainage area (observed and frequency analysis)
(h) _____ Correlation of Paired Stations (daily, monthly)
(i) _____ Dependable flows
(j) _____ "Paired" station comparisons

Groundwater:
(a) _____ Mean Annual water level, Sd and Cv
(b) _____ Mean Monthly water level, Sd and Cv
(c) _____ Present available physical data (lithologies, pump tests, and transmissivities).

11. Approximate Dollar Value of Programs to which the preceding Hydrologic Data are contributing:

$

12. Are you aware of any recent studies which might provide additional useful information for this network assessment? Please reference:

13. Are you aware of any specific users of groundwater and/or surface water data and analyses? Please refer to attached mailing list and list any additional names below.

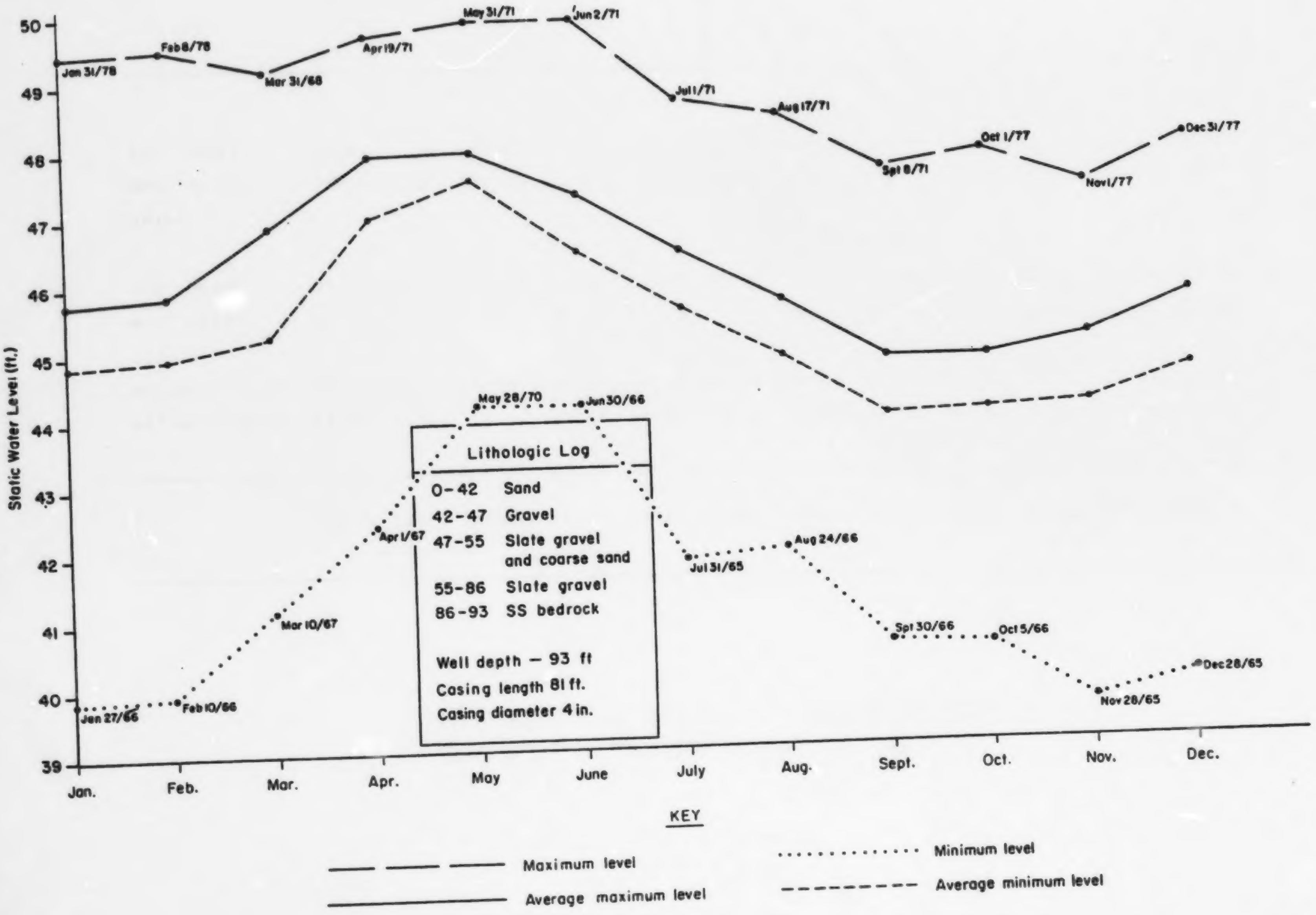
14. Comments:

APPENDIX B

COLDBROOK N.S.D.O.E. OBSERVATION WELL 001 FEBRUARY 1965-1983

STATIC WATER LEVEL READINGS IN FEET ABOVE SEA LEVEL

	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
AV. MAX. LEVEL	45.77	45.87	46.87	47.91	47.94	47.31	46.44	45.65	44.80	44.80	45.07	45.65
AV. MIN. LEVEL	44.86	44.93	45.25	46.99	47.53	46.45	45.58	44.82	43.92	44.00	44.05	44.54
MAX. LEVEL	49.48	49.52	49.18	49.70	49.90	49.88	48.65	48.40	47.58	47.82	47.32	47.98
MIN. LEVEL	39.87	39.90	41.13	42.38	44.15	44.15	41.83	41.95	40.53	40.48	39.62	40.00
Dates												
MAX. LEVEL	31/78	8/78	31/68	19/71	31/71	2/71	1/71	17/71	8/71	1/77	1/77	31/77
MIN. LEVEL	27/66	10/66	10/67	1/67	28/70	30/66	31/65	29/66	30/66	5/66	28/65	28/65

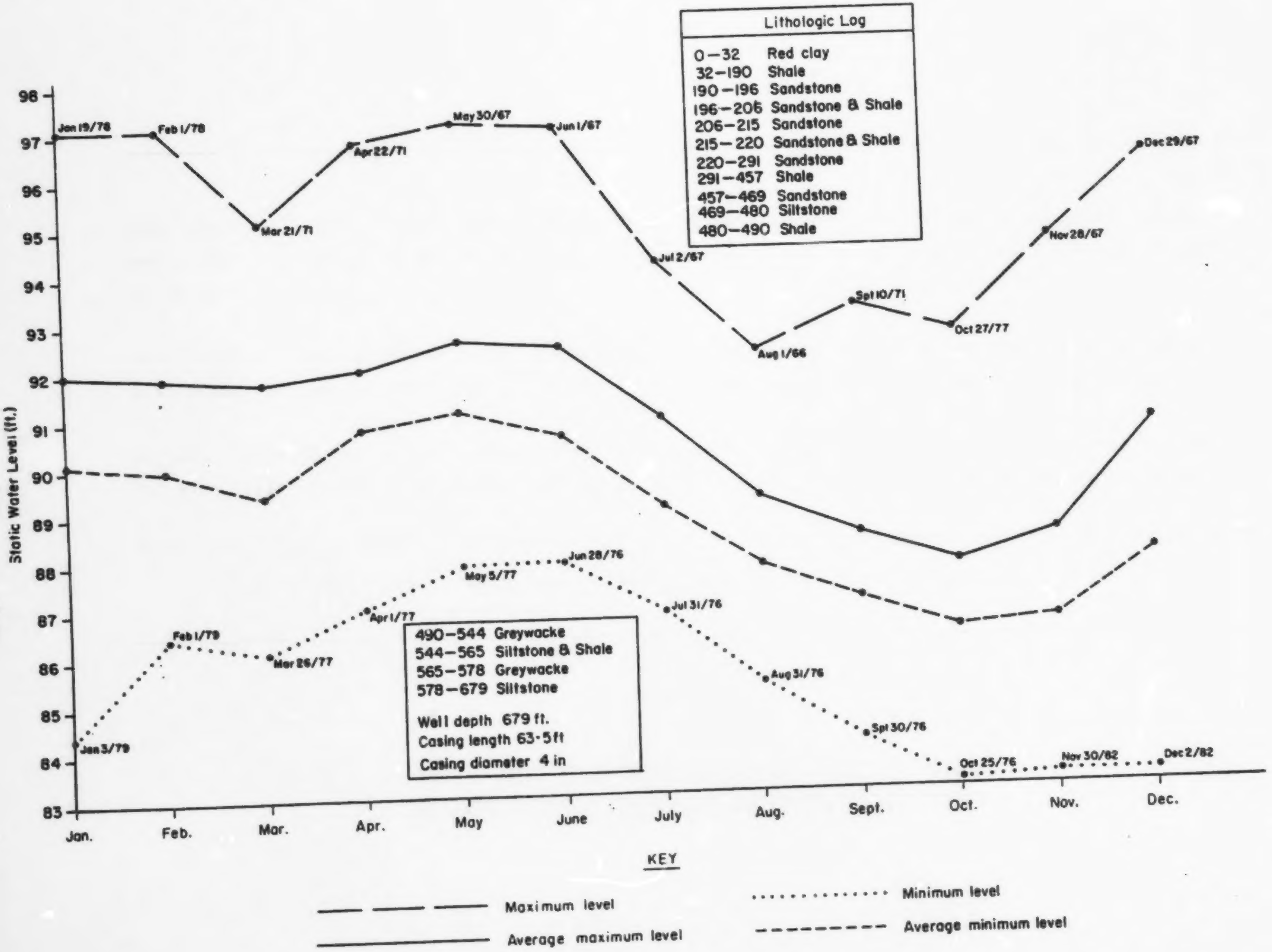


FEBRUARY 1965 — 1983

TRURO N.S.D.O.E. OBSERVATION WELL 002 1966 - 1983

STATIC WATER LEVEL READINGS IN FEET ABOVE SEA LEVEL

	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
AV. MAX. LEVEL	92.00	91.92	91.77	92.03	92.59	92.41	90.90	89.22	88.40	87.77	88.36	90.62
AV. MIN. LEVEL	90.10	89.97	89.41	90.75	91.11	90.57	89.04	87.75	87.03	86.37	86.54	87.90
MAX. LEVEL	97.08	97.08	95.12	96.73	97.12	97.01	94.13	92.23	93.18	92.60	94.50	96.20
MIN. LEVEL	84.43	86.42	86.12	87.00	87.84	87.89	86.83	85.29	84.08	83.17	83.24	83.24
Dates												
MAX. LEVEL	19/78	1/78	21/71	22/71	30/67	1/67	2/67	1/66	10/71	27/77	28/67	29/67
MIN. LEVEL	3/79	1/79	26/77	1/77	5/77	28/76	31/76	31/76	30/76	25/76	30/82	2/82



Lithologic Log	
0–32	Red clay
32–190	Shale
190–196	Sandstone
196–206	Sandstone & Shale
206–215	Sandstone
215–220	Sandstone & Shale
220–291	Sandstone
291–457	Shale
457–469	Sandstone
469–480	Siltstone
480–490	Shale
490–544	Greywacke
544–565	Siltstone & Shale
565–578	Greywacke
578–679	Siltstone

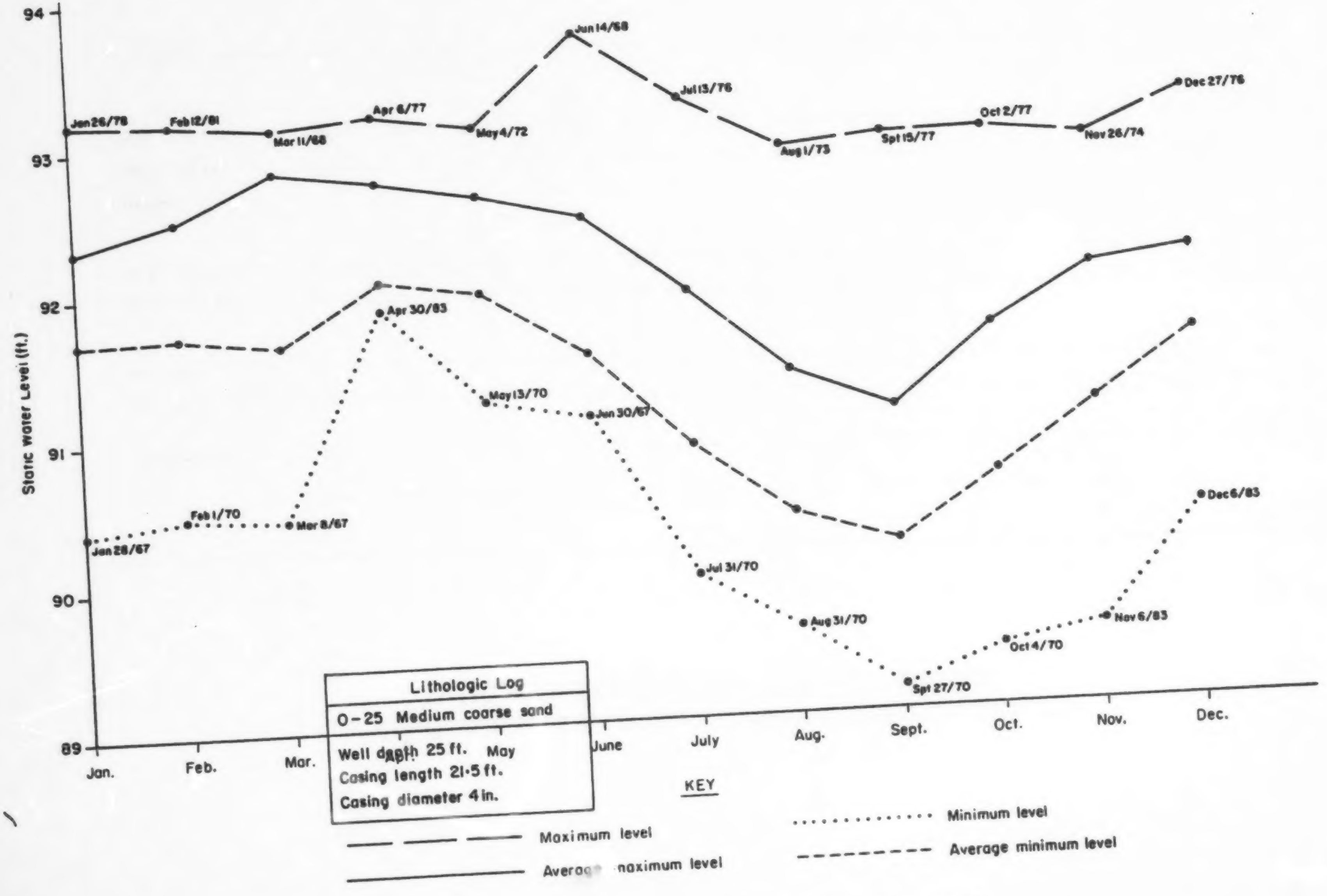
Well depth 679 ft.
Casing length 63·5 ft
Casing diameter 4 in

TRURO-N.S.D.O.E.-OBSERVATION WELL 002, 1966-1983

GREENWOOD N.S.D.O.E. OBSERVATION WELL 003 1967 - 1983

STATIC WATER LEVEL READINGS IN FEET ABOVE SEA LEVEL

	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
AV. MAX. LEVEL	92.93	92.51	92.82	92.73	92.61	92.43	91.91	91.34	91.08	91.60	91.99	92.05
AV. MIN. LEVEL	91.69	91.71	91.64	92.05	91.95	91.51	90.86	90.38	90.15	90.60	91.06	91.50
MAX. LEVEL	93.18	93.16	93.11	93.16	93.07	93.68	93.22	92.87	92.96	92.93	92.86	93.14
MIN. LEVEL	90.41	90.48	90.44	91.85	91.20	91.08	89.98	89.60	89.16	89.42	89.54	90.33
Dates												
MAX. LEVEL	26/78	12/81	11/68	6/77	4/72	14/68	13/76	1/73	15/77	2/77	26/74	27/76
MIN. LEVEL	28/67	1/70	8/67	30/83	13/70	30/67	31/70	31/70	27/70	4/70	6/83	6/83

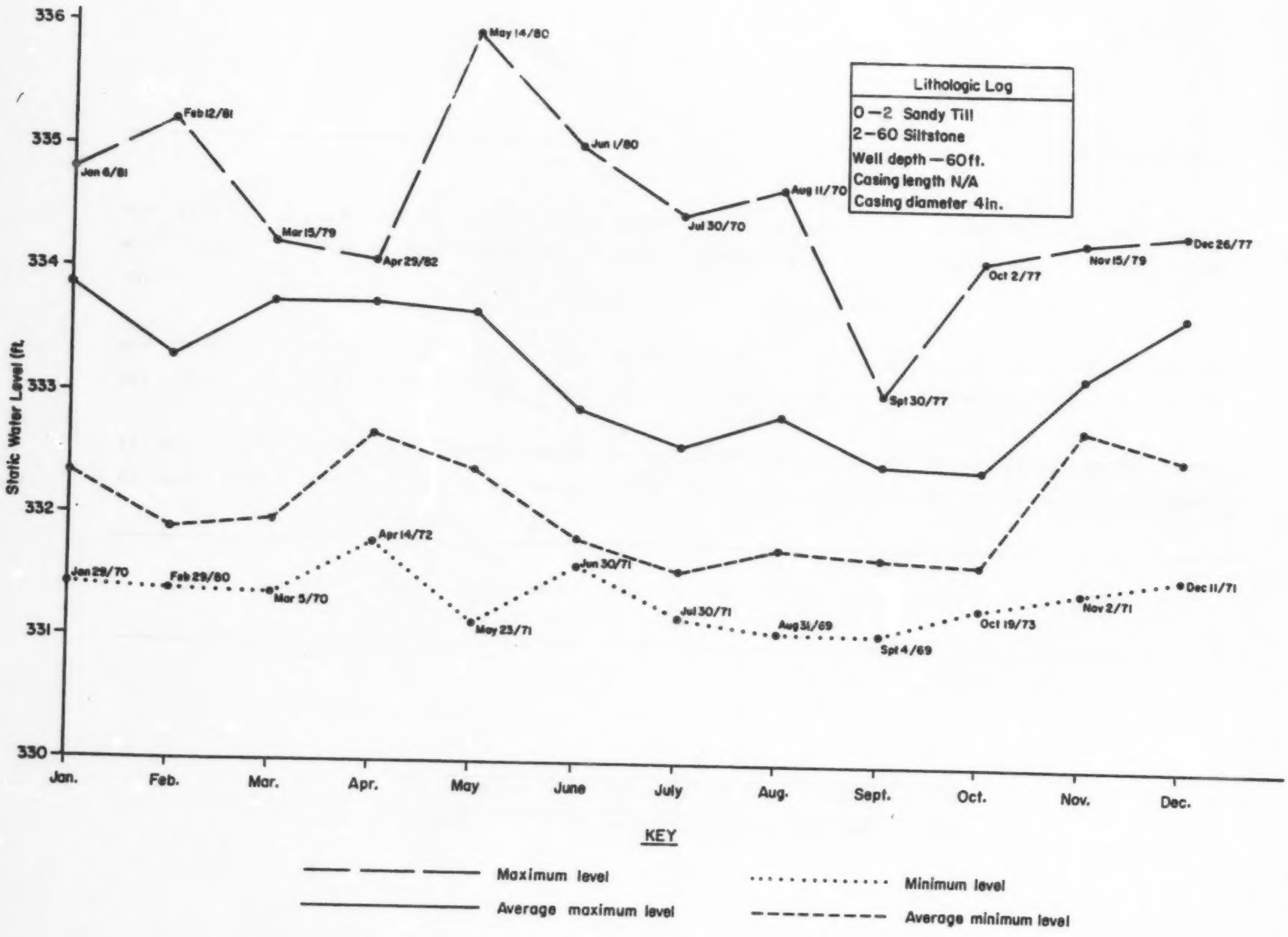


GREENWOOD–N.S.D.O.E. OBSERVATION WELL 003, 1967–1983

FRASER BROOK N.S.D.O.E. OBSERVATION WELL 004 1967-1974, 1976-1983

STATIC WATER LEVEL READINGS IN FEET ABOVE SEA LEVEL

	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
AV. MAX. LEVEL	333.87	333.30	333.74	333.75	333.68	332.90	332.60	332.84	332.48	332.44	333.20	333.72
AV. MIN. LEVEL	332.32	331.88	331.96	332.71	332.39	332.81	331.57	331.76	331.68	331.66	333.76	332.53
MAX. LEVEL	334.81	335.21	334.22	333.82	335.94	335.03	334.49	334.70	333.03	334.15	334.30	334.38
MIN. LEVEL	331.44	331.40	331.35	331.78	331.14	331.61	331.20	331.10	331.08	331.30	331.44	331.56
Dates												
MAX. LEVEL	6/81	12/81	15/79	14/71	14/80	1/80	30/70	11/70	30/77	2/77	15/79	26/77
MIN. LEVEL	29/70	29/80	5/70	14/72	23/71	30/71	30/71	31/69	4/69	19/73	2/71	11/71

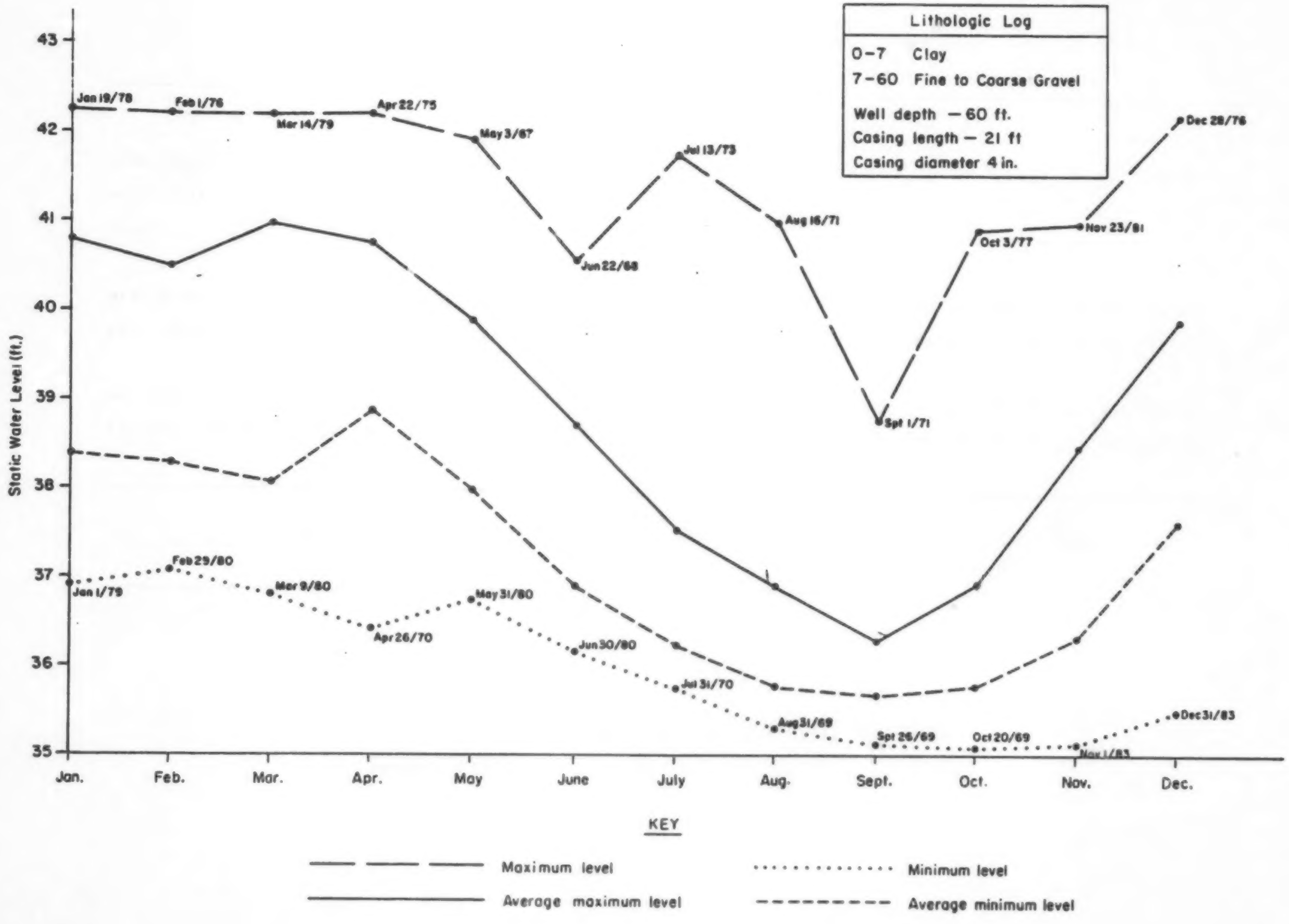


FRASER BROOK—N.S.D.O.E. OBSERVATION WELL 004, 1967-1974, 1976-1983

WILMOT N.S.D.O.E. OBSERVATION WELL 005 1967 - 1983

STATIC WATER LEVEL READINGS IN FEET ABOVE SEA LEVEL

	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
AV. MAX. LEVEL	40.79	40.50	40.97	40.77	39.88	38.70	37.53	36.92	36.28	36.94	38.47	39.91
AV. MIN. LEVEL	38.39	38.25	38.05	38.86	37.99	36.90	36.24	35.79	35.67	35.77	36.33	37.60
MAX. LEVEL	42.24	42.21	42.20	42.20	41.90	40.57	41.76	41.00	38.80	40.93	41.00	42.19
MIN. LEVEL	36.92	37.07	36.80	37.00	36.73	36.14	35.75	35.30	35.13	35.09	35.13	35.50
Dates												
MAX. LEVEL	19/78	1/76	14/79	22/75	3/67	22/68	13/73	16/71	1/71	3/77	23/81	28/76
MIN. LEVEL	1/79	29/80	9/80	26/70	31/80	30/80	31/70	31/69	26/69	20/69	1/83	31/83

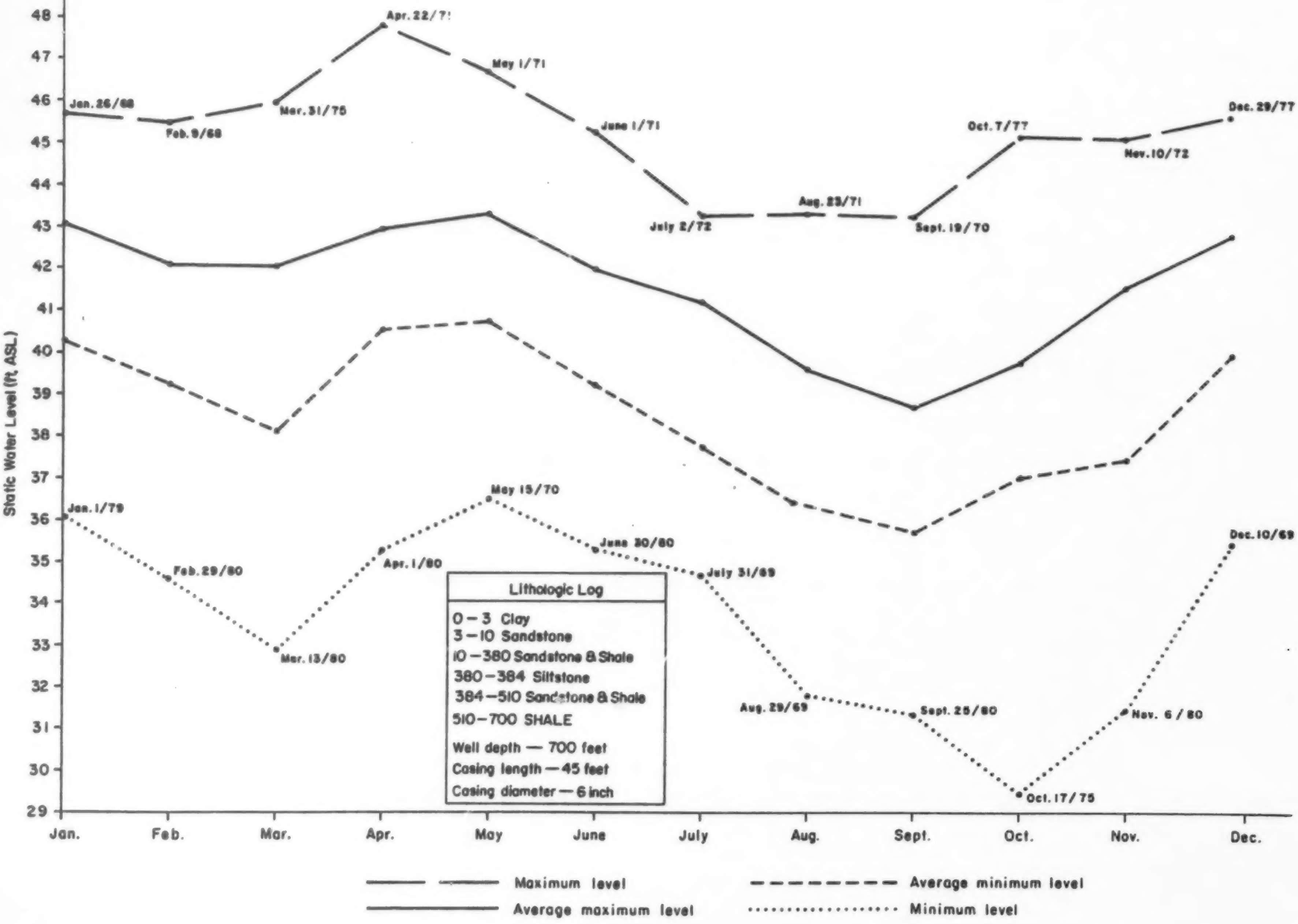


WILMOT—N.S.D.O.E. OBSERVATION WELL 005, 1967-1983

AMHERST N.S.D.O.E. OBSERVATION WELL 006 JULY 1967-1980

STATIC WATER LEVEL READINGS IN FEET ABOVE SEA LEVEL

	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
AV. MAX. LEVEL	43.11	42.11	42.07	42.97	43.38	41.97	41.20	39.61	38.72	39.75	41.59	42.86
AV. MIN. LEVEL	40.29	39.22	38.14	40.58	40.82	39.24	37.77	36.50	35.73	37.03	37.43	39.95
MAX. LEVEL	45.73	45.49	46.03	47.80	46.70	45.34	43.40	43.45	43.40	45.23	45.12	45.73
MIN.LEVEL	36.09	34.60	32.85	35.25	36.57	35.56	34.69	31.80	31.31	29.47	31.44	35.45
Dates												
MAX. LEVEL	26/68	9/68	31/75	22/71	1/71	1/71	2/72	23/71	19/70	7/77	10/72	29/77
MIN. LEVEL	1/79	29/80	13/80	1/80	15/70	30/80	31/69	29/69	25/80	17/75	6/80	10/69

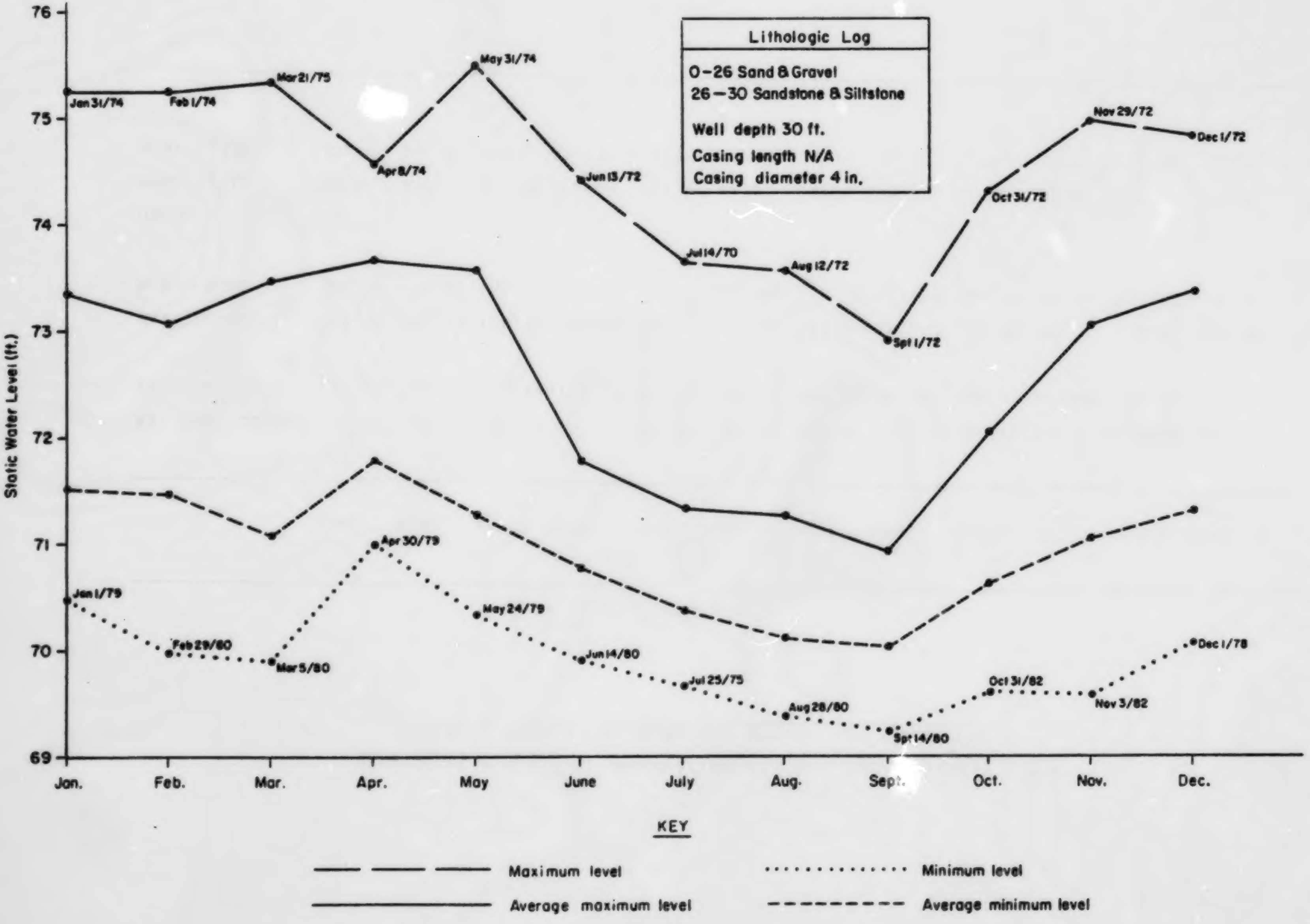


AMHERST–N.S.D.O.E. OBSERVATION WELL 006, JULY 1967–1980

MURRAY SIDING N.S.D.O.E. OBSERVATION WELL 007 1968-1970, 1972, 1974-1983

STATIC WATER LEVEL READINGS IN FEET ABOVE SEA LEVEL

	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
AV. MAX. LEVEL	73.37	73.07	73.49	73.68	73.57	71.78	71.35	71.26	70.94	72.05	73.05	73.37
AV. MIN. LEVEL	71.54	71.49	71.09	71.78	71.27	70.78	70.39	70.13	70.03	70.64	71.05	71.31
MAX. LEVEL	75.26	75.26	75.35	74.58	75.50	74.44	73.67	73.57	72.92	74.32	74.98	74.84
MIN. LEVEL	70.49	69.98	69.91	70.99	70.34	69.93	69.68	69.37	69.24	69.63	70.07	70.07
Dates												
MAX. LEVEL	31/74	1/74	21/75	8/74	31/74	13/72	14/70	12/72	1/72	31/72	29/72	1/72
MIN. LEVEL	1/79	29/80	5/80	30/79	24/79	14/80	25/75	28/80	14/80	31/82	3/82	1/78

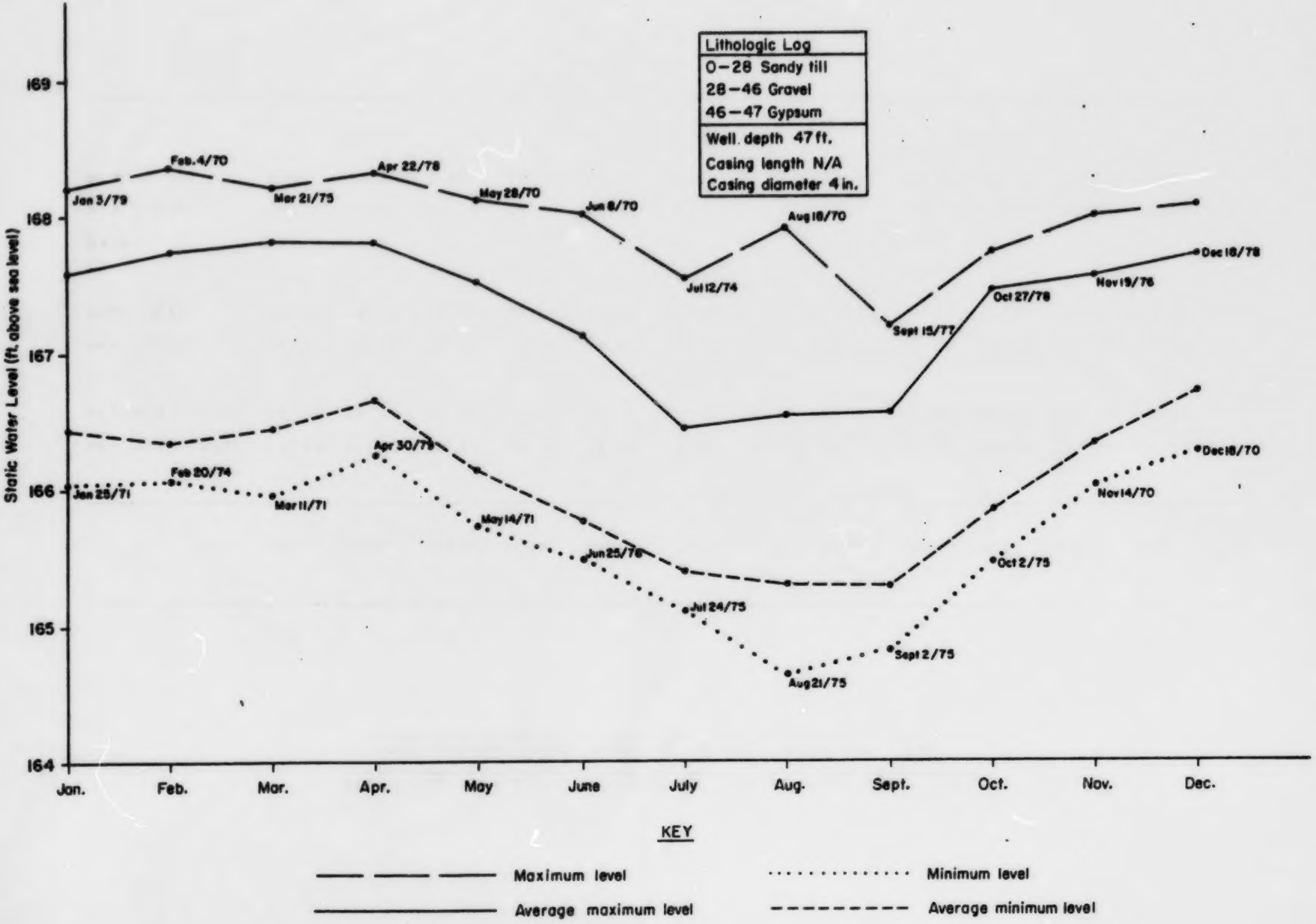


MURRAY SIDING-N.S.D.O.E. OBSERVATION WELL 007-1968-1970, 1972, 1974-1983

GILLISDALE N.S.D.O.E. OBSERVATION WELL 008 1969 - AUGUST -1979

STATIC WATER LEVEL READINGS IN FEET ABOVE SEA LEVEL

	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
AV. MAX. LEVEL	167.59	167.76	167.83	167.82	167.52	167.13	166.46	166.53	166.56	167.45	167.55	167.71
AV. MIN. LEVEL	166.45	166.37	166.45	166.67	166.13	165.76	165.39	165.30	165.28	165.85	166.32	166.70
MAX. LEVEL	168.21	168.38	168.22	168.33	168.13	168.02	167.56	167.92	167.20	167.74	168.00	168.08
MIN. LEVEL	166.02	166.06	165.97	166.24	165.72	165.48	165.08	164.63	164.81	165.46	166.02	166.26
Dates												
MAX. LEVEL	3/79	4/70	21/75	22/78	28/70	8/70	12/74	18/77	15/77	27/78	19/76	18/78
MIN. LEVEL	25/71	20/74	11/71	30/79	14/71	25/76	24/75	21/75	2/75	2/75	14/70	18/70

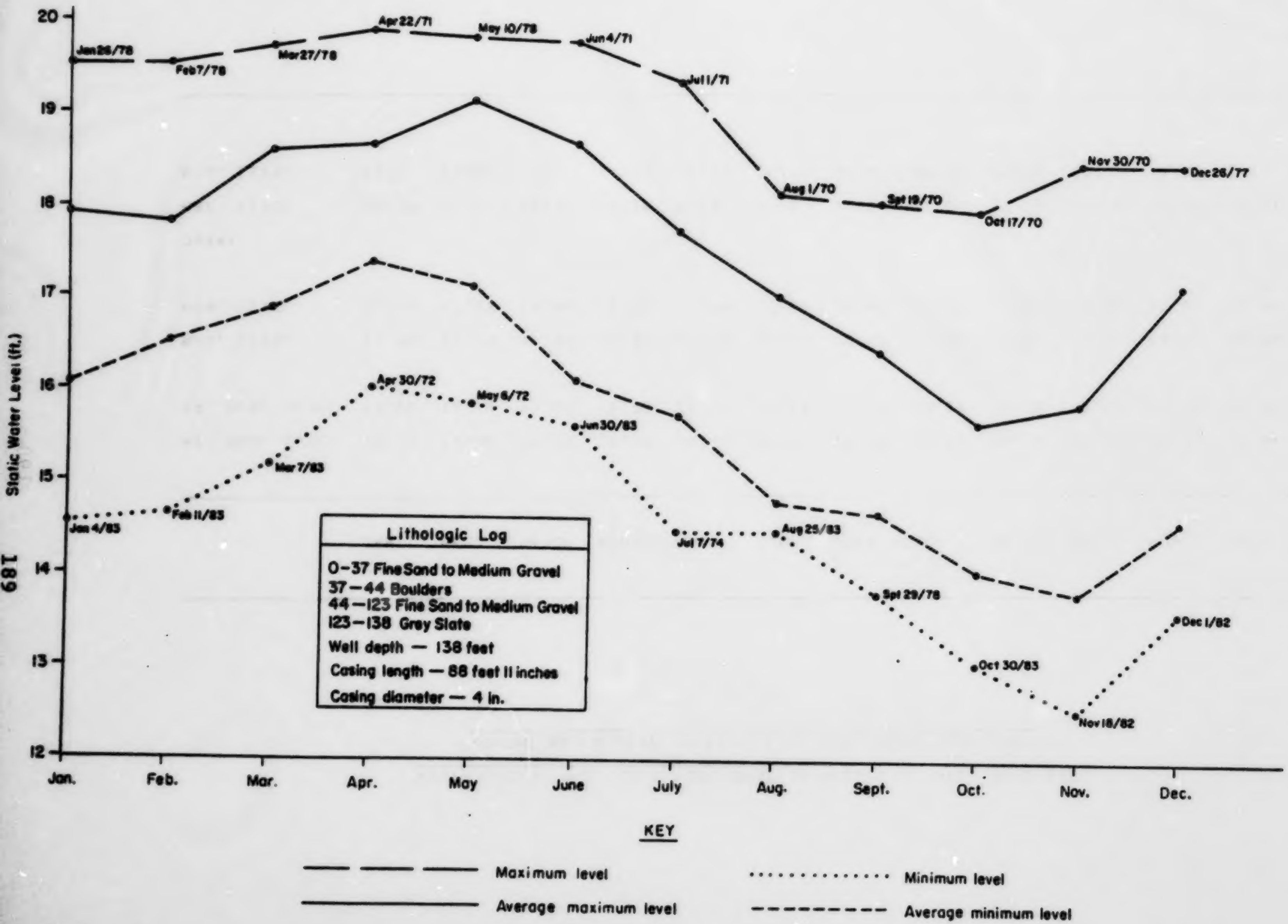


GILLISDALE–N.S.D.O.E. OBSERVATION WELL 008, 1969–AUGUST 1974.

WOLFVILLE I N.S.D.O.E. OBSERVATION WELL 009 1970 - 1983

STATIC WATER LEVEL READINGS IN FEET ABOVE SEA LEVEL

	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
AV. MAX. LEVEL	17.92	17.82	18.61	18.68	17.74	17.08	16.46	17.08	16.46	15.66	15.89	17.20
AV. MIN. LEVEL	16.07	16.55	17.89	17.41	17.13	16.13	15.75	14.82	14.69	14.06	14.83	14.62
MAX. LEVEL	19.52	19.53	19.73	19.90	19.83	19.80	19.38	18.17	18.08	18.00	18.52	18.52
MIN. LEVEL	14.55	14.65	15.20	16.04	15.87	15.62	14.50	14.50	13.81	13.06	12.55	13.65
Dates												
MAX. LEVEL	26/78	7/78	27/78	22/71	10/78	4/71	1/71	1/70	19/70	17/70	30/70	26/77
MIN. LEVEL	4/83	11/83	7/83	30/72	6/72	30/83	7/74	25/83	29/78	30/83	18/82	1/82



Lithologic Log

0–37 Fine Sand to Medium Gravel
37—44 Boulders
44—123 Fine Sand to Medium Gravel
123—138 Grey Slate

Well depth — 138 feet

Casing length — 88 feet 11 inches

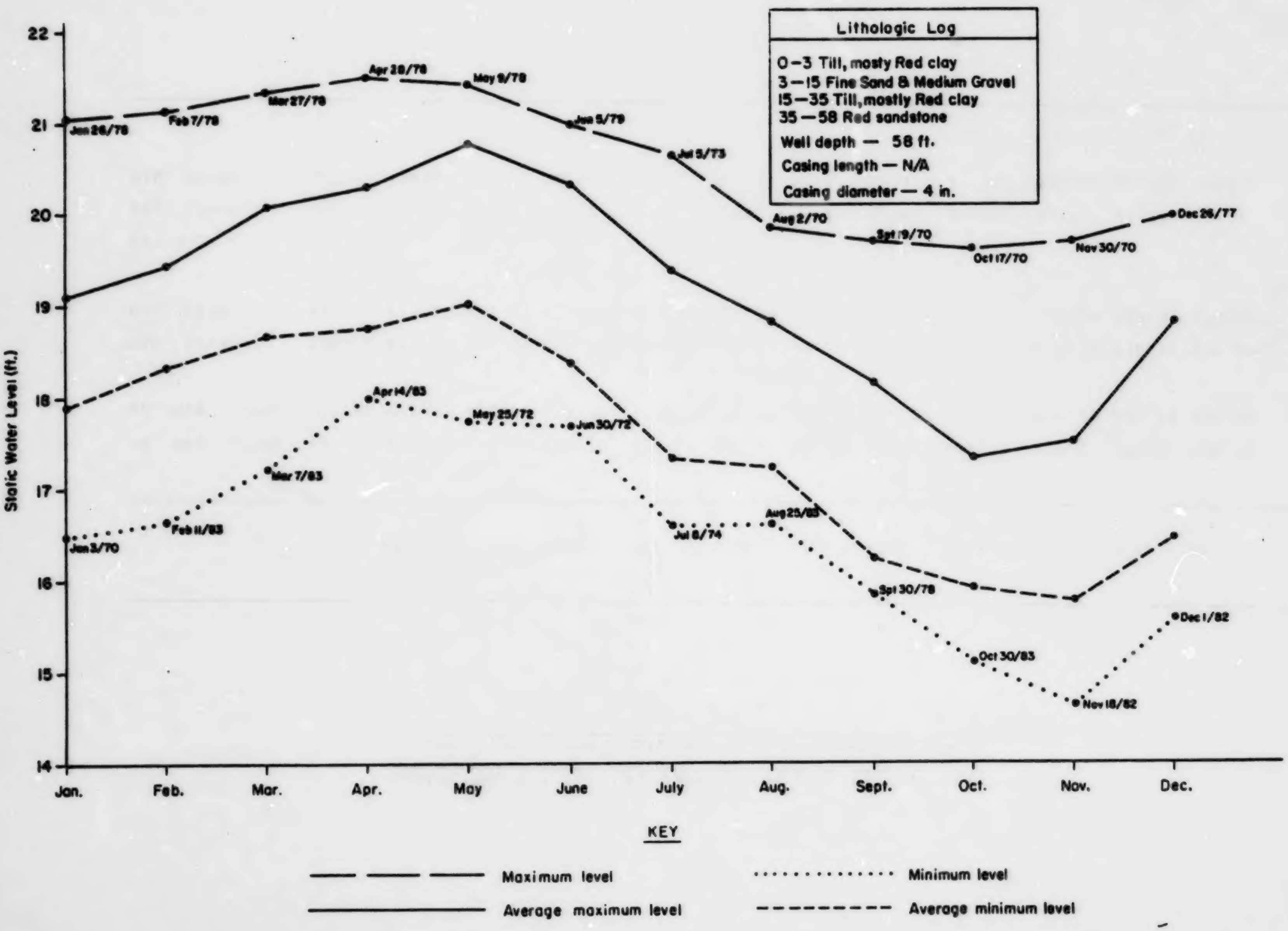
Casing diameter — 4 in.

WOLFVILLE I-N.S.D.O.E. OBSERVATION WELL 009, 1970-1983

WOLFVILLE 2 N.S.D.O.E. OBSERVATION WELL 010 1970, 1972-1983

STATIC WATER LEVEL READINGS IN FEET ABOVE SEA LEVEL

	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
AV. MAX. LEVEL	19.10	19.46	20.09	20.30	20.78	20.33	19.39	18.82	18.14	17.34	17.52	19.84
AV. MIN. LEVEL	17.90	18.36	18.69	18.78	19.03	18.37	17.34	17.24	16.24	15.93	15.79	16.46
MAX. LEVEL	21.06	21.13	21.34	21.50	21.43	20.99	20.63	19.85	19.71	19.63	19.71	19.99
MIN. LEVEL	16.48	17.65	17.84	18.04	17.74	17.69	16.59	16.95	15.85	15.20	15.03	15.98
Dates												
MAX. LEVEL	26/78	7/78	27/78	28/78	9/78	5/79	5/73	2/70	19/70	17/70	30/70	26/77
MIN. LEVEL	3/70	11/83	7/83	14/83	25/72	30/72	8/74	25/83	30/78	30/83	18/82	1/82



Lithologic Log

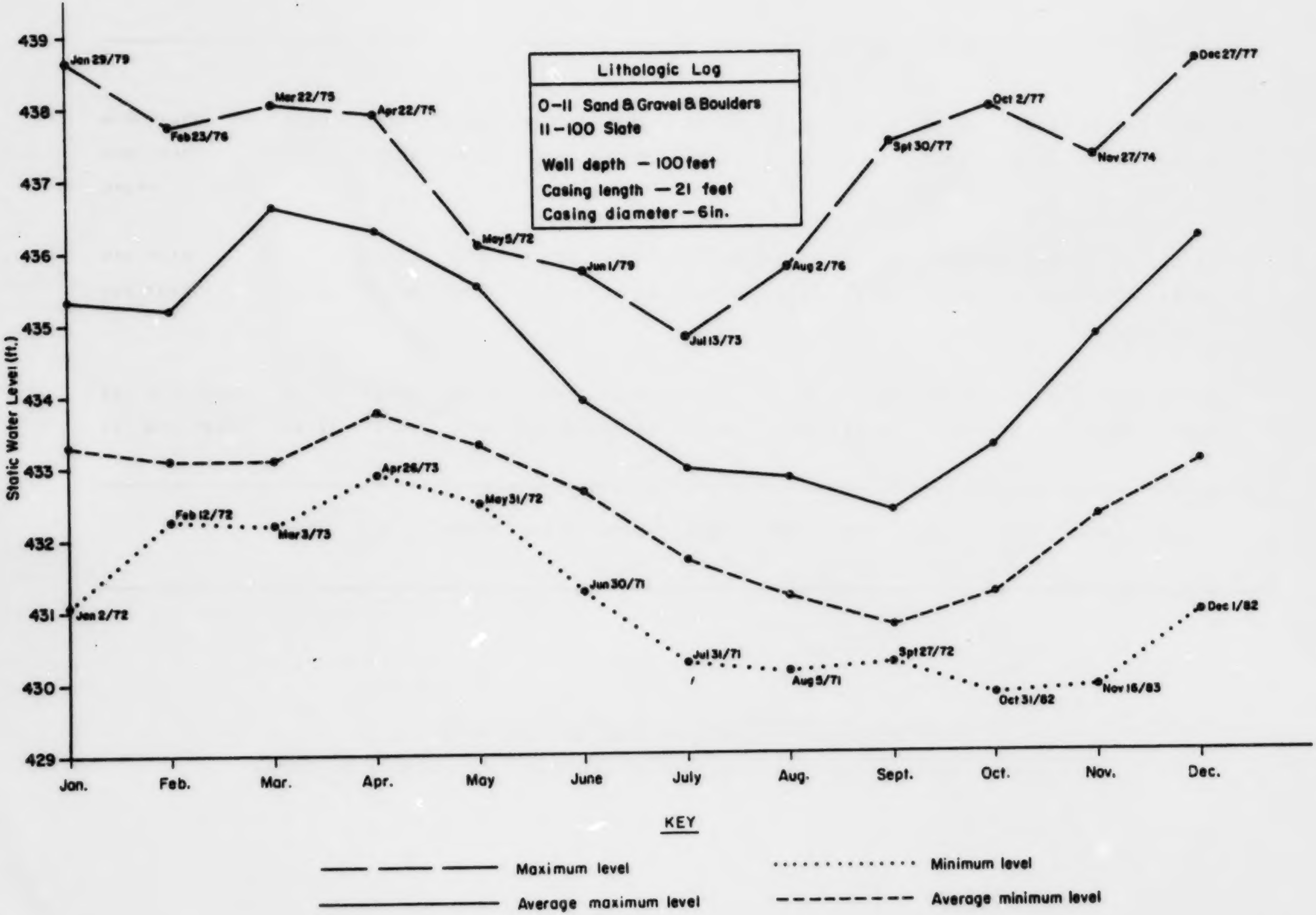
0–3 Till, mosty Red clay
3–15 Fine Sand & Medium Gravel
15–35 Till, mostly Red clay
35–58 Red sandstone
Well depth — 58 ft.
Casing length — N/A
Casing diameter — 4 in.

WOLFVILLE 2 – N.S.D.O.E. – OBSERVATION WELL 010, 1970, 1972–1983

SHARPE BROOK N.S.D.O.E. OBSERVATION WELL 011 1971-1983

STATIC WATER LEVEL READINGS IN FEET ABOVE SEA LEVEL

	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
AV. MAX. LEVEL	435.33	435.19	436.63	436.29	435.51	433.94	432.95	432.84	432.36	433.27	434.80	436.15
AV. MIN. LEVEL	433.32	433.13	433.12	433.77	433.32	432.65	431.69	431.21	430.78	431.25	432.28	433.07
MAX. LEVEL	438.66	437.78	438.06	437.92	436.10	435.73	434.80	435.76	437.50	437.98	436.58	438.64
MIN. LEVEL	431.10	432.27	432.33	432.92	432.49	431.28	430.28	430.16	430.28	429.84	429.94	430.95
Dates												
MAX. LEVEL	29/79	23/76	22/75	22/75	5/72	1/79	13/73	2/76	30/77	2/77	27/74	27/77
MIN. LEVEL	2/72	12/72	3/73	26/73	31/72	30/71	31/71	5/71	27/72	31/82	16/83	1/82

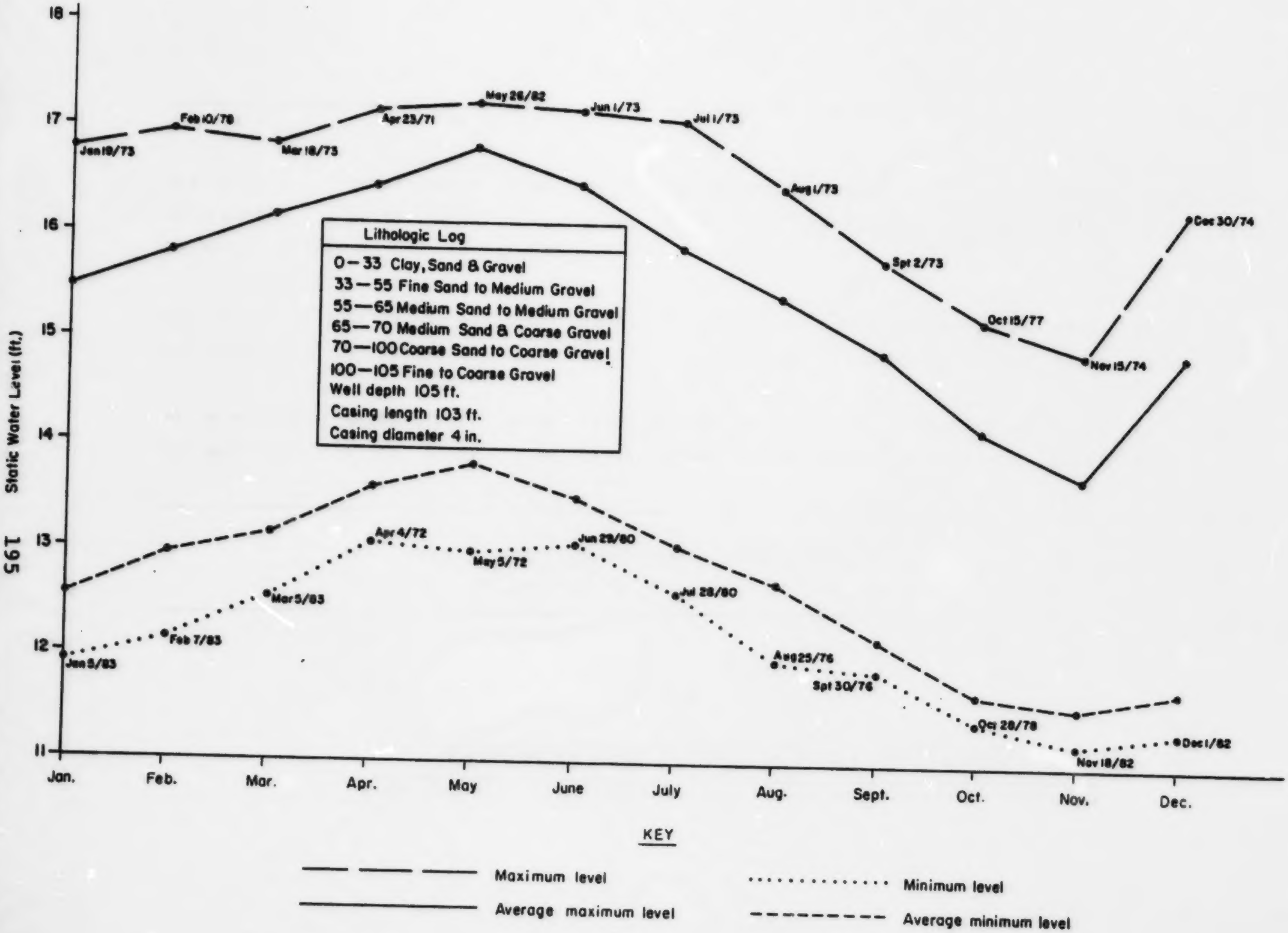


SHARPE BROOK – N.S.D.O.E. OBSERVATION WELL 011, 1971–1983

WOLFVILLE 3 N.S.D.O.E. OBSERVATION WELL 012 APRIL 1971 - 1974, 1976 - 1983

STATIC WATER LEVEL READINGS IN FEET ABOVE SEA LEVEL

	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
AV. MAX LEVEL	15.47	15.82	16.17	16.46	16.82	16.49	15.89	15.44	14.92	14.19	13.75	14.92
AV. MIN LEVEL	12.57	12.96	13.15	13.60	13.83	13.51	13.08	12.72	12.18	11.68	11.55	12.73
MAX LEVEL	16.77	16.96	16.85	17.16	17.25	17.19	17.10	16.43	15.79	15.23	14.92	16.30
MIN LEVEL	11.92	12.15	12.55	13.07	13.60	13.06	12.61	11.98	11.89	11.40	11.21	11.33
Dates												
MAX LEVEL	19/73	10/78	18/73	23/71	26/82	1/73	1/73	1/73	2/73	15/77	15/74	30/74
MIN LEVEL	5/83	7/83	5/83	4/72	5/72	29/80	28/80	25/76	30/76	28/78	18/82	1/82

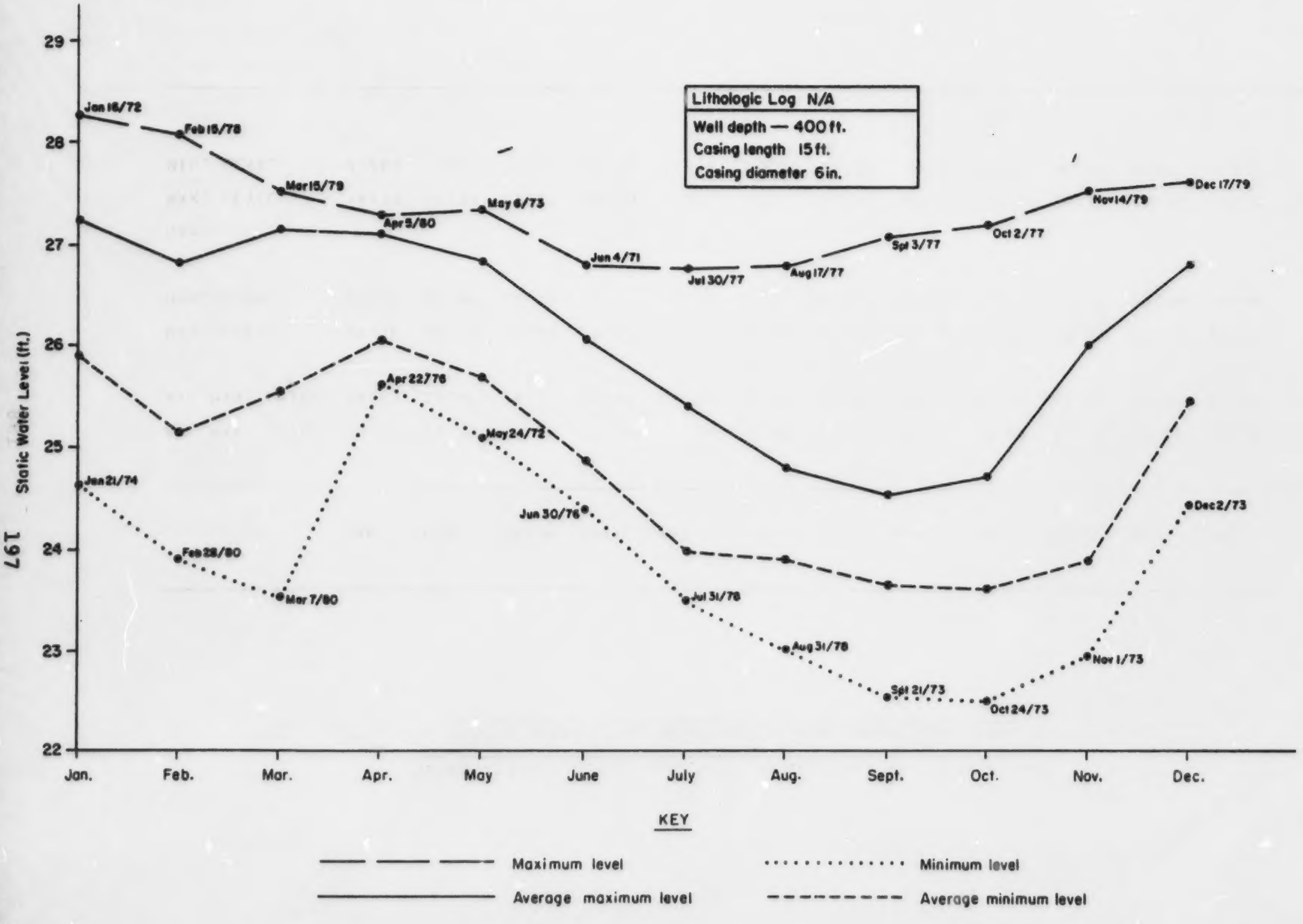


WOLFVILLE 3—N.S.D.O.E. OBSERVATION WELL 012, 1971–1974, 1976–1983

TRURO 420 N.S.D.O.E. OBSERVATION WELL 013 MAY 1971-1974, 1976-1983

STATIC WATER LEVEL READINGS IN FEET ABOVE SEA LEVEL

	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
AV. MAX LEVEL	27.23	26.83	27.16	27.11	26.84	26.07	25.41	24.80	24.52	24.71	26.01	26.81
AV. MIN LEVEL	25.90	25.14	25.56	26.08	25.69	24.86	23.97	23.91	23.64	23.61	23.87	25.47
MAX LEVEL	28.23	28.08	27.50	27.30	27.36	26.82	26.77	26.81	27.09	27.21	27.55	27.64
MIN LEVEL	24.63	23.91	23.51	25.61	25.10	24.39	23.49	23.00	22.54	22.51	22.96	24.44
Dates												
MAX LEVEL	16/72	15/78	15/79	5/80	6/73	4/71	30/77	17/77	3/77	2/77	14/79	17/79
MIN LEVEL	21/74	28/80	7/80	22/76	24/72	30/76	31/78	31/78	21/73	24/73	1/73	2/73

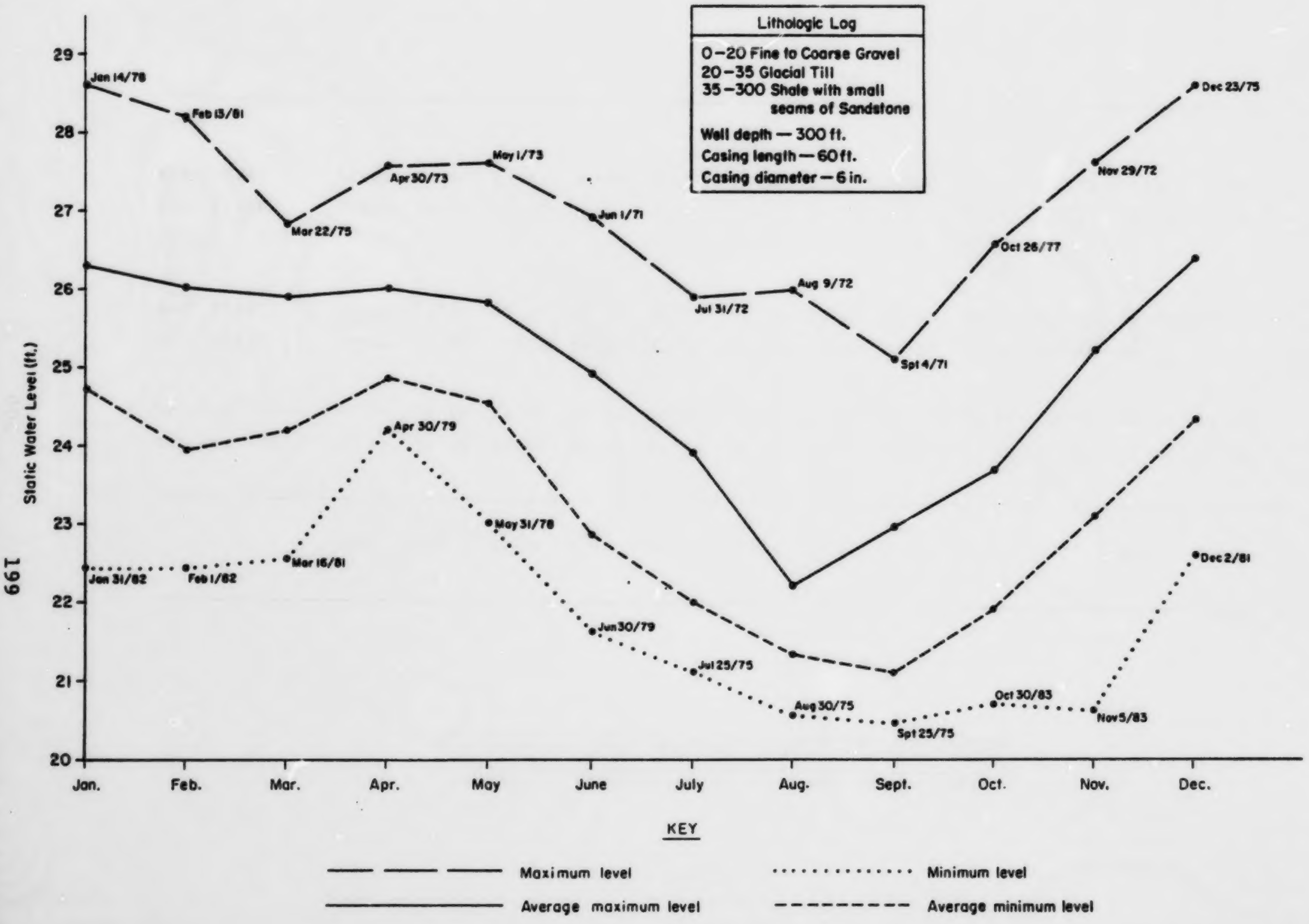


TRURO 420-N.S.D.O.E. OBSERVATION WELL 013, MAY 1971-1974, 1976-1983

TRURO 421 N.S.D.O.E. OBSERVATION WELL 014 MAY 1971 - 1983

STATIC WATER LEVEL READINGS IN FEET ABOVE SEA LEVEL

	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
AV. MAX. LEVEL	26.28	26.00	25.88	26.00	25.84	24.93	23.91	22.23	22.97	23.71	25.22	26.36
AV. MIN. LEVEL	24.73	23.96	24.20	24.86	24.54	22.87	22.02	21.36	21.13	21.93	23.11	24.34
MAX. LEVEL	28.56	28.16	26.84	27.57	27.60	26.92	25.88	26.00	25.10	26.58	27.62	28.56
MIN. LEVEL	22.46	22.46	22.58	24.22	23.01	21.64	21.14	20.56	20.49	20.72	20.64	22.62
Dates												
MAX. LEVEL	14/78	13/81	22/75	30/73	1/33	1/71	31/72	9/72	4/71	26/77	29/72	23/75
MIN. LEVEL	31/82	1/82	16/81	30/79	31/78	30/79	25/75	30/75	25/75	30/83	5/83	2/81

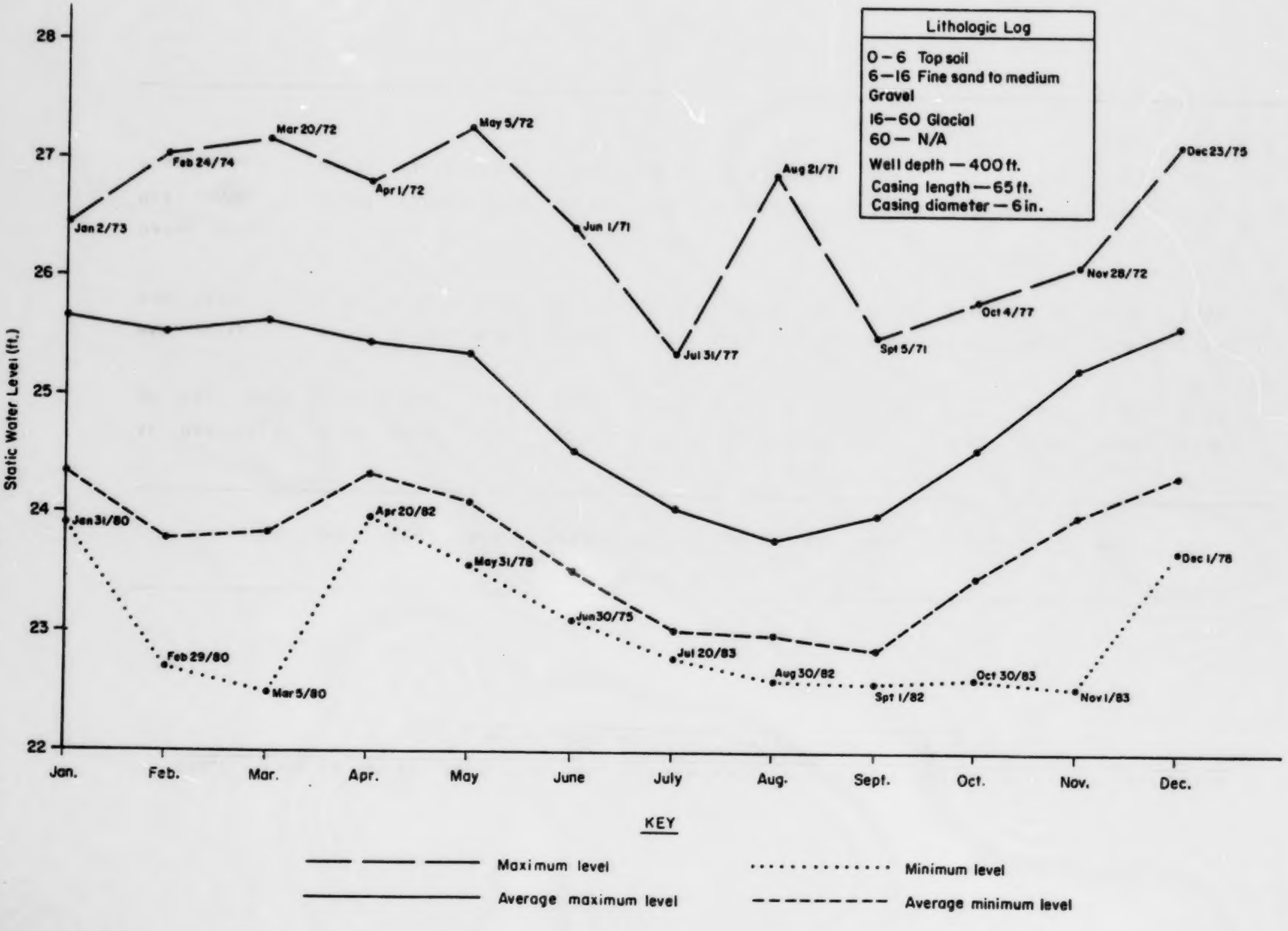


TRURO 421—N.S.D.O.E. OBSERVATION WELL 014, MAY 1971—1983

TRURO 422 OBSERVATION WELL 015 May 1971 - 1983

STATIC WATER LEVEL READINGS IN FEET ABOVE SEA LEVEL

	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
AV. MAX. LEVEL	26.65	25.52	25.62	25.45	25.35	24.52	24.03	23.79	24.00	24.56	25.25	25.59
AV. MIN. LEVEL	24.34	23.78	23.84	24.33	24.09	23.52	23.03	23.01	22.86	23.49	23.99	24.35
MAX. LEVEL	26.45	27.02	27.15	26.78	27.25	26.41	25.35	26.86	25.50	25.81	26.12	27.12
MIN. LEVEL	23.91	22.71	22.51	23.95	23.57	23.13	22.79	22.61	22.59	22.62	22.57	23.71
Dates												
MAX. LEVEL	2/73	24/74	20/72	1/72	5/72	1/71	31/77	21/71	5/71	4/77	28/72	23/75
MIN. LEVEL	31/80	29/80	5/80	20/82	31/78	30/75	20/83	30/82	1/82	30/83	1/83	1/78

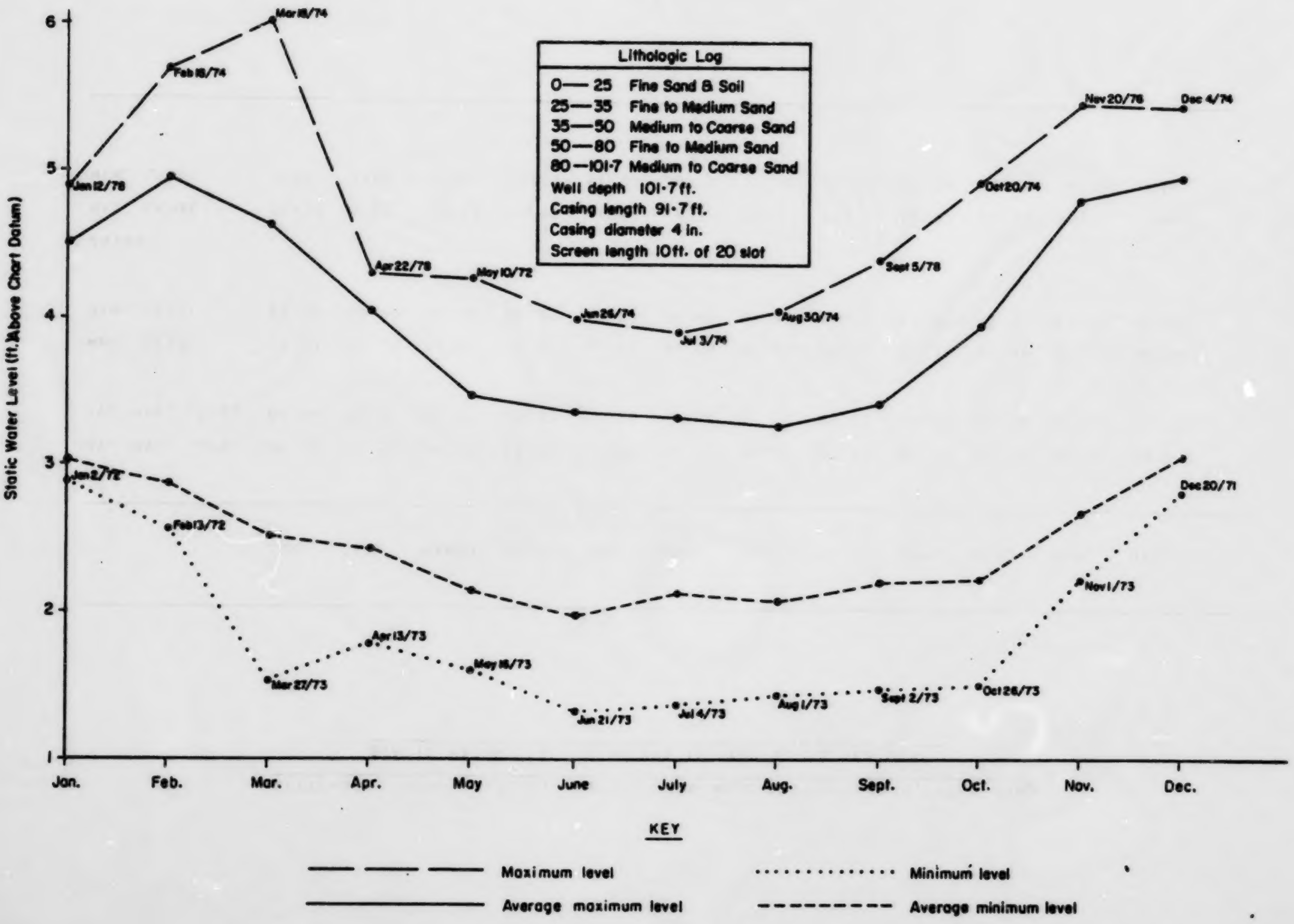


TRURO 422 — N.S.D.O.E. OBSERVATION WELL 015, MAY 1971 — 1983

SABLE ISLAND 19 NSDOE OBSERVATION WELL 016 NOVEMBER 1971-1974, FEBRUARY 1976 - SEPTEMBER 1978

STATIC WATER LEVEL READINGS IN FEET ABOVE CHART DATUM

	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
AV. MAX. LEVEL	4.51	4.96	4.63	4.05	3.48	3.36	3.33	3.27	3.43	3.96	4.81	4.96
AV. MIN. LEVEL	3.03	2.88	2.52	2.43	2.15	1.99	2.14	2.09	2.21	2.23	2.68	3.07
MAX. LEVEL	4.90	5.69	6.01	4.30	4.27	4.00	3.92	4.06	4.40	4.93	5.47	5.44
MIN. LEVEL	2.89	2.57	1.54	1.79	1.61	1.34	1.38	1.44	1.48	1.51	2.22	2.82
Dates												
MAX. LEVEL	12/78	18/74	18/74	22/78	10/72	26/74	3/74	30/76	5/78	20/74	20/76	4/74
MIN. LEVEL	2/72	13/72	27/73	13/73	16/73	21/73	4/73	1/73	2/73	26/73	1/71	20/71

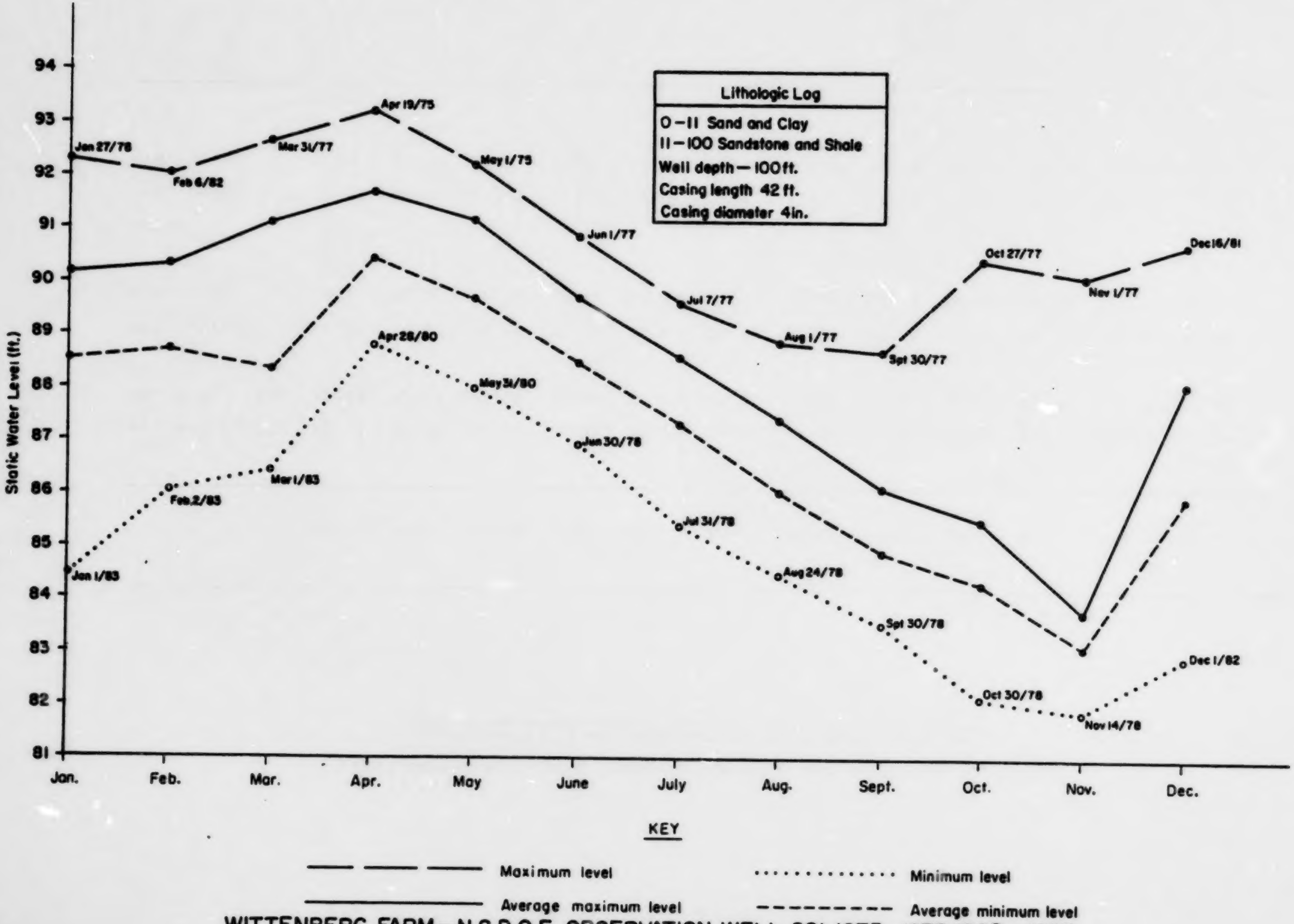


SABLE ISLAND 19-N.S.D.O.E. OBSERVATION WELL 016, NOVEMBER 1971-1974, FEBRUARY 1976-SEPTEMBER 1978

WITTENBERG FARM N.S.D.O.E. OBSERVATION WELL 021 1975-1978, 1980-1983

STATIC WATER LEVEL READINGS IN FEET ABOVE SEA LEVEL

	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
AV. MAX. LEVEL	90.18	90.36	91.13	91.71	91.21	89.76	88.61	87.43	86.17	85.54	83.82	88.17
AV. MIN. LEVEL	88.54	88.72	88.37	90.48	89.72	88.52	87.33	86.07	84.92	84.36	83.18	85.97
MAX. LEVEL	92.33	92.10	92.68	93.24	92.26	90.88	89.64	88.90	88.73	90.48	90.16	90.79
MIN. LEVEL	84.48	86.05	86.47	88.82	87.98	86.96	85.42	84.50	83.57	82.17	81.92	82.94
Dates												
MAX. LEVEL	27/78	6/82	31/77	19/75	1/75	1/77	7/77	1/77	30/77	27/77	1/77	16/81
MIN. LEVEL	1/83	2/83	1/83	28/80	31/80	30/78	31/78	24/78	30/78	30/78	14/78	1/82



Lithologic Log

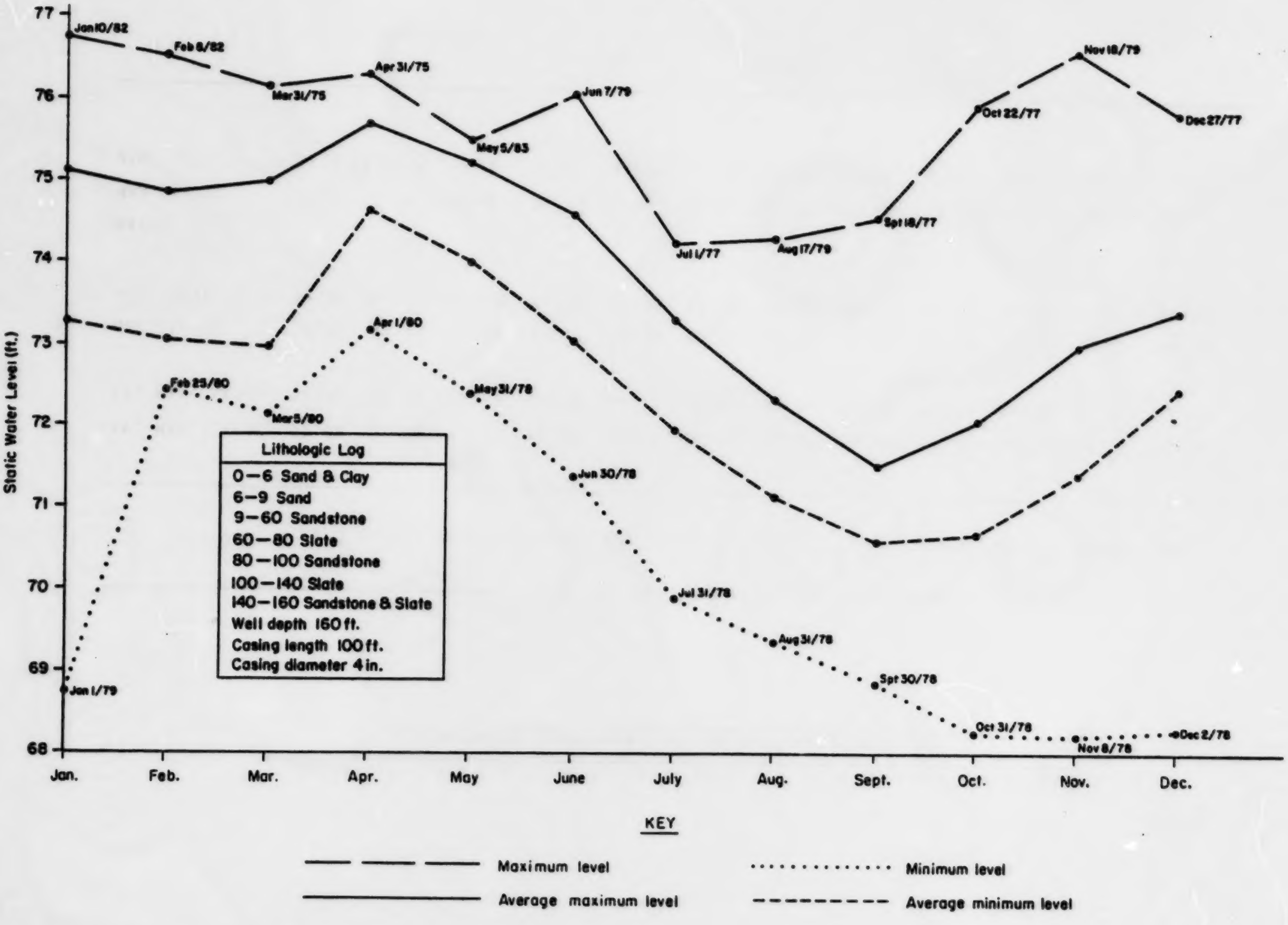
0–11 Sand and Clay
11–100 Sandstone and Shale
Well depth – 100 ft.
Casing length 42 ft.
Casing diameter 4in.

WITTENBERG FARM--N.S.D.O.E. OBSERVATION WELL 021, 1975–1978, 1980–1983

LOWER CANARD N.S.D.O.E. OBSERVATION WELL 022 SEPTEMBER 1974-1983

STATIC WATER LEVEL READINGS IN FEET ABOVE SEA LEVEL

	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
AV. MAX. LEVEL	75.13	74.85	74.99	75.71	75.23	74.60	73.32	72.35	71.53	72.06	73.00	74.06
AV. MIN. LEVEL	73.29	73.06	72.99	74.66	74.01	73.05	71.96	71.16	70.59	70.70	71.42	72.45
MAX. LEVEL	76.76	76.51	76.16	76.31	75.51	76.07	74.25	74.30	74.56	75.93	76.60	75.84
MIN. LEVEL	68.76	72.46	72.16	73.16	72.39	71.38	69.90	69.37	68.86	68.26	68.21	68.28
Dates												
MAX. LEVEL	10/82	8/82	31/75	31/75	5/83	7/79	1/77	17/79	18/77	22/77	18/79	27/77
MIN. LEVEL	1/79	25/80	5/80	1/80	31/78	30/78	31/78	31/78	30/78	31/78	8/78	2/78

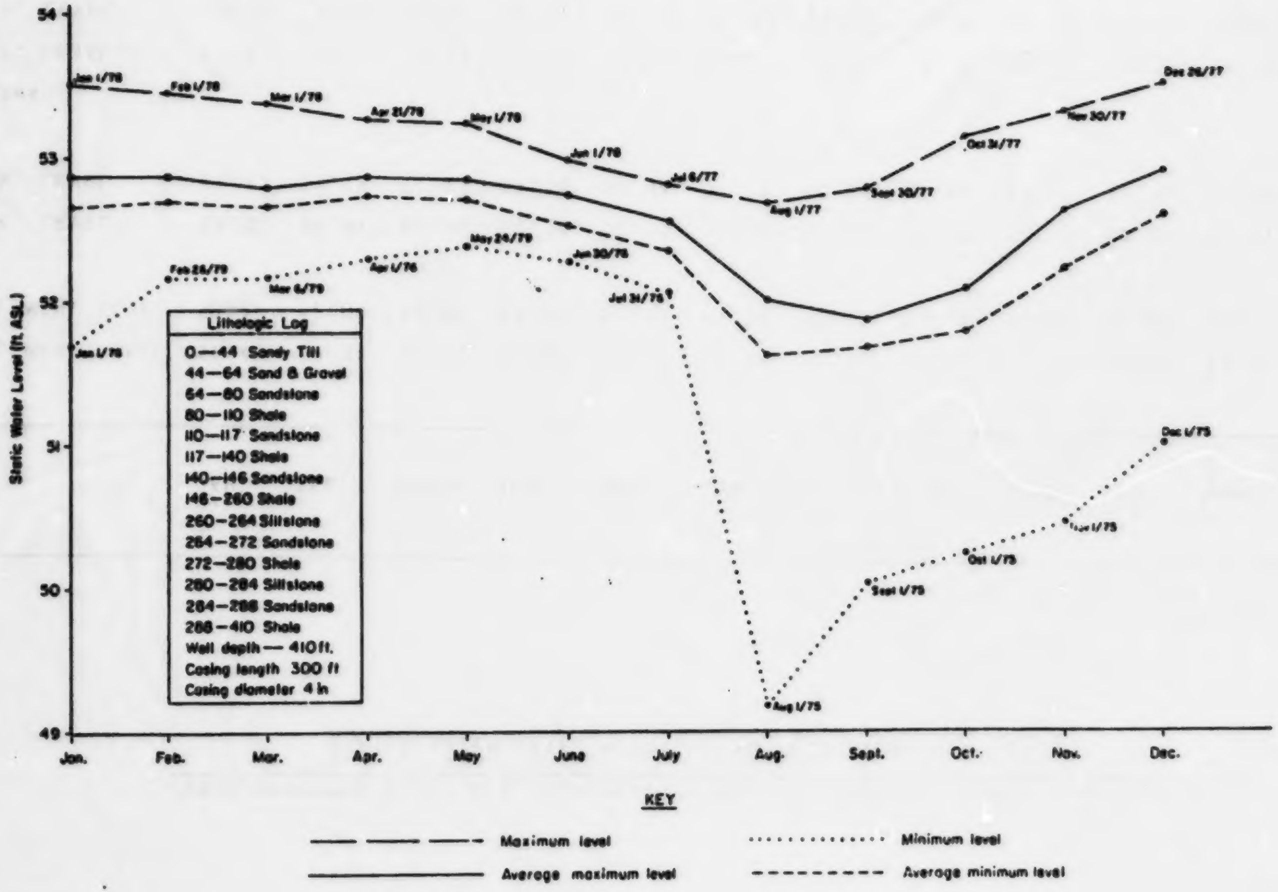


LOWER CANARD N.S.D.O.E. OBSERVATION WELL 022 - SEPTEMBER 1974—1983

THREE BROOKS 6 N.S.D.O.E. OBSERVATION WELL 023 AUGUST, 1975 - AUGUST 1980

STATIC WATER LEVEL READINGS IN FEET ABOVE SEA LEVEL

	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
AV. MAX. LEVEL	52.86	52.86	52.78	52.86	52.85	52.73	52.54	51.99	51.85	52.06	52.59	52.88
AV. MIN. LEVEL	52.67	52.70	52.65	52.72	52.71	52.52	52.34	51.61	51.65	51.76	52.19	52.57
MAX. LEVEL	53.51	53.46	53.37	53.26	53.23	52.97	52.80	52.66	52.76	53.12	53.29	53.48
MIN. LEVEL	51.69	52.16	52.15	52.29	52.38	52.26	52.05	49.17	50.02	50.02	50.43	50.98
Dates												
MAX. LEVEL	1/78	1/78	1/78	21/78	1/78	1/78	6/77	1/77	30/77	31/77	30/77	26/77
MIN. LEVEL	1/76	26/79	6/79	1/76	24/79	30/76	31/76	1/75	1/75	1/75	1/75	1/75



Lithologic Log	
0—44	Sandy Till
44—64	Sand & Gravel
64—80	Sandstone
80—110	Shale
110—117	Sandstone
117—140	Shale
140—146	Sandstone
146—260	Shale
260—264	Siltstone
264—272	Sandstone
272—280	Shale
280—284	Siltstone
284—288	Sandstone
288—410	Shale

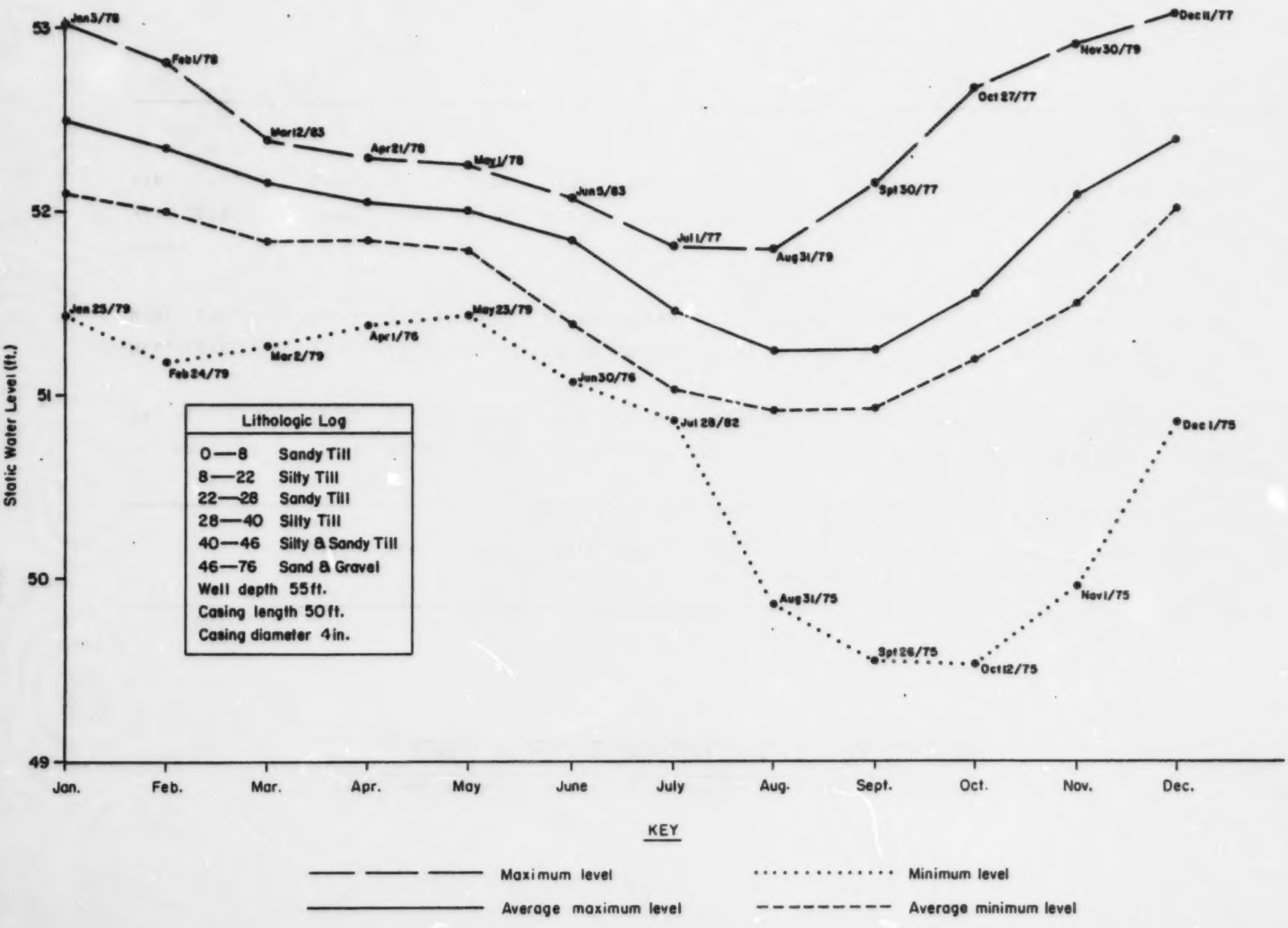
Well depth — 410 ft.
Casing length 300 ft
Casing diameter 4 in

THREE BROOKS 6-N.S.D.O.E. OBSERVATION WELL 023, AUGUST 1975-AUGUST 1980

THREE BROOKS 5 N.S.D.O.E. OBSERVATION WELL 024 AUGUST, 1975 - AUGUST 1983

STATIC WATER LEVEL READINGS IN FEET ABOVE SEA LEVEL

	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
AV. MAX. LEVEL	52.49	52.34	52.15	52.05	52.01	51.84	51.46	51.24	51.25	51.55	52.09	52.39
AV. MIN. LEVEL	52.10	52.00	51.84	51.85	51.78	51.39	51.03	50.92	50.93	51.20	51.50	52.01
MAX. LEVEL	53.02	55.81	52.39	52.30	52.25	52.07	51.81	51.80	52.15	52.67	52.91	53.07
MIN. LEVEL	51.43	51.18	51.27	51.38	51.44	51.07	50.86	49.86	49.55	49.54	49.96	50.85
Dates												
MAX. LEVEL	3/78	1/78	12/83	21/78	1/78	5/83	1/77	31/79	30/77	27/77	30/79	11/77
MIN. LEVEL	25/79	24/79	2/79	1/76	23/79	30/76	28/82	31/75	26/75	12/75	1/75	1/75

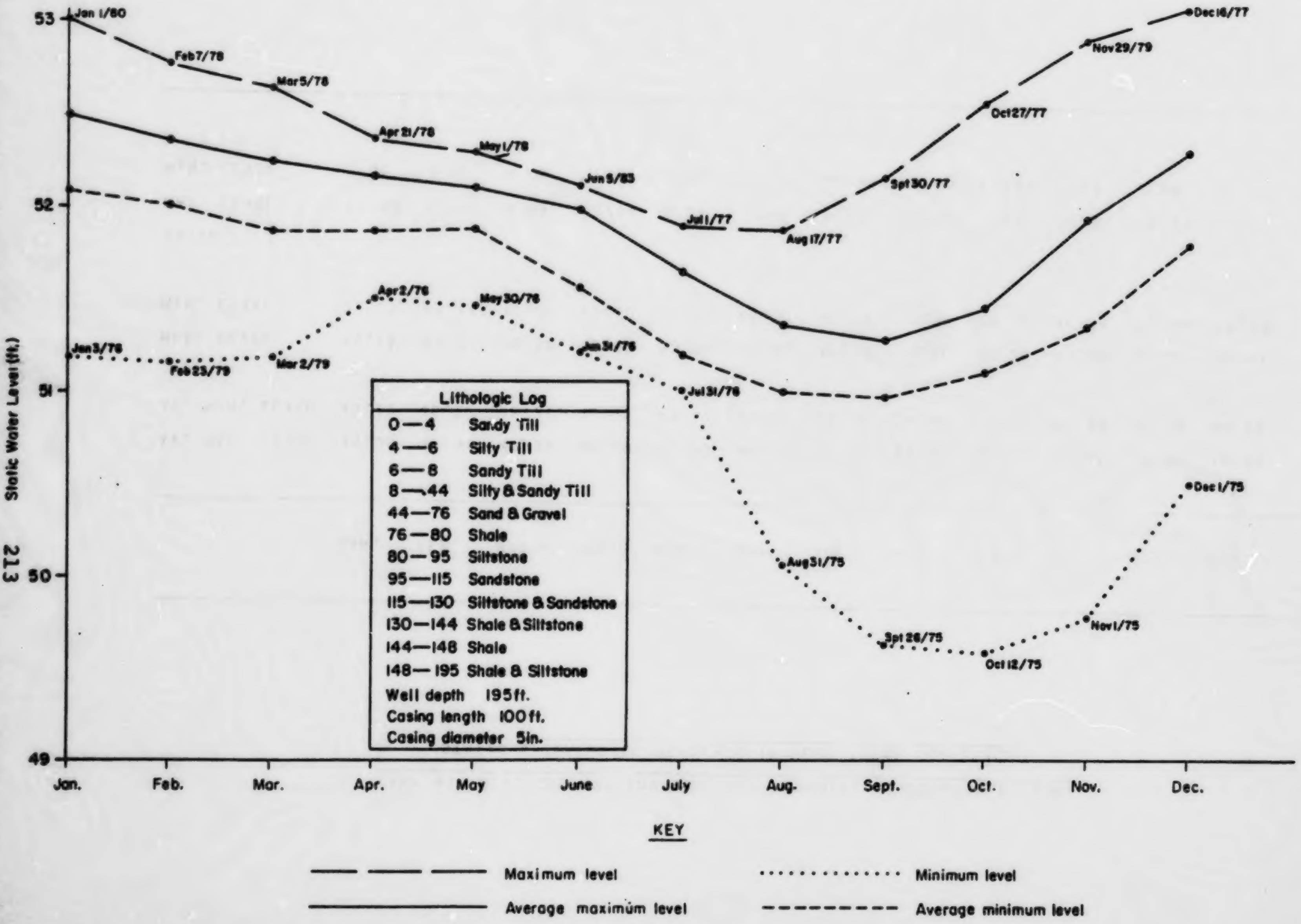


THREE BROOKS 5-N.S.D.O.E. OBSERVATION WELL 024, AUGUST 1975-1983

THREE BROOKS 4 N.S.D.O.E. OBSERVATION WELL 025 AUGUST 1975 - 1983

STATIC WATER LEVEL READINGS IN FEET ABOVE SEA LEVEL

	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
AV. MAX. LEVEL	52.49	52.35	52.24	52.16	52.10	51.98	51.64	51.36	51.28	51.46	51.94	52.29
AV. MIN. LEVEL	52.08	52.00	51.86	51.87	51.87	51.55	51.20	51.00	50.97	51.11	51.35	51.79
MAX. LEVEL	53.01	52.77	52.63	52.36	52.29	52.11	51.89	51.87	52.16	52.55	52.89	53.06
MIN. LEVEL	51.19	51.15	51.18	51.49	51.46	51.21	51.01	50.06	49.63	49.58	49.78	50.50
Dates												
MAX. LEVEL	1/80	7/78	5/78	21/78	1/78	5/83	1/77	17/77	30/77	27/77	29/79	10/77
MIN. LEVEL	3/76	23/79	2/79	2/76	30/76	31/76	31/76	31/75	26/75	12/75	1/75	1/75



Lithologic Log	
0—4	Sandy Till
4—6	Silty Till
6—8	Sandy Till
8—44	Silty & Sandy Till
44—76	Sand & Gravel
76—80	Shale
80—95	Siltstone
95—115	Sandstone
115—130	Siltstone & Sandstone
130—144	Shale & Siltstone
144—148	Shale
148—195	Shale & Siltstone

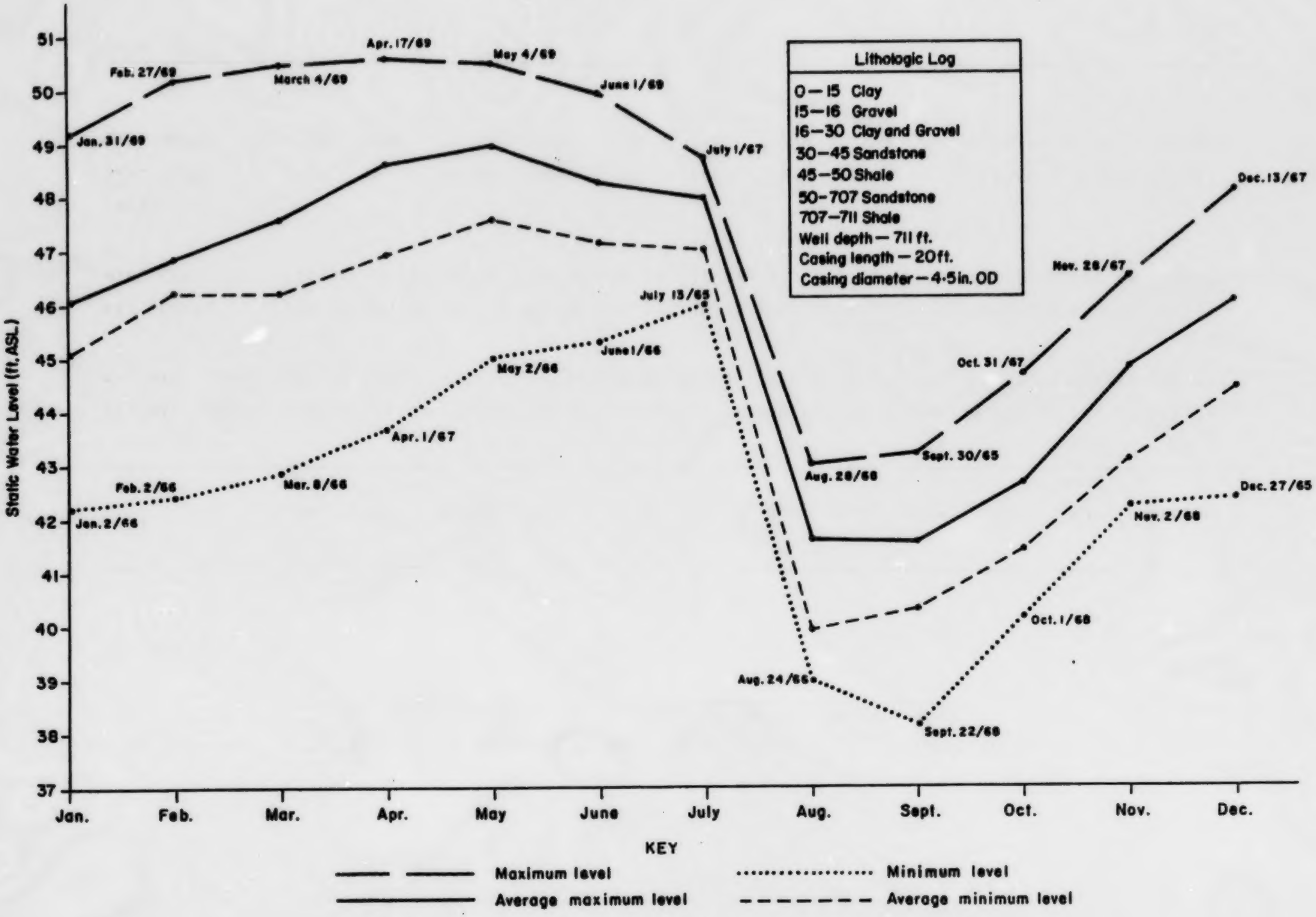
Well depth 195ft.
Casing length 100ft.
Casing diameter 5in.

THREE BROOKS 4-N.S.D.O.E. OBSERVATION WELL 025, AUGUST 1975-1983

CANNING N.S. OBSERVATION WELL 031 FEBRUARY, 1965 - JULY, 1969

STATIC WATER LEVEL READINGS IN FEET ABOVE SEA LEVEL

	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
AV. MAX. LEVEL	46.06	46.86	47.59	48.69	49.00	48.28	48.00	41.59	41.55	42.65	44.80	46.04
AV. MIN. LEVEL	45.12	46.22	46.21	46.96	47.62	47.17	47.05	39.94	40.27	41.37	43.08	44.47
MAX. LEVEL	49.19	50.21	50.50	50.60	50.51	49.98	48.77	43.00	43.20	44.68	46.51	48.11
MIN. LEVEL	42.21	42.44	42.85	43.70	45.00	45.31	46.00	38.99	38.12	40.16	42.20	42.32
Dates												
MAX. LEVEL	31/69	27/69	4/69	17/69	4/69	1/69	1/67	28/68	30/65	31/67	28/67	13/67
MIN. LEVEL	2/66	2/66	8/66	1/67	2/66	1/66	13/65	24/66	22/68	1/68	2/68	27/65

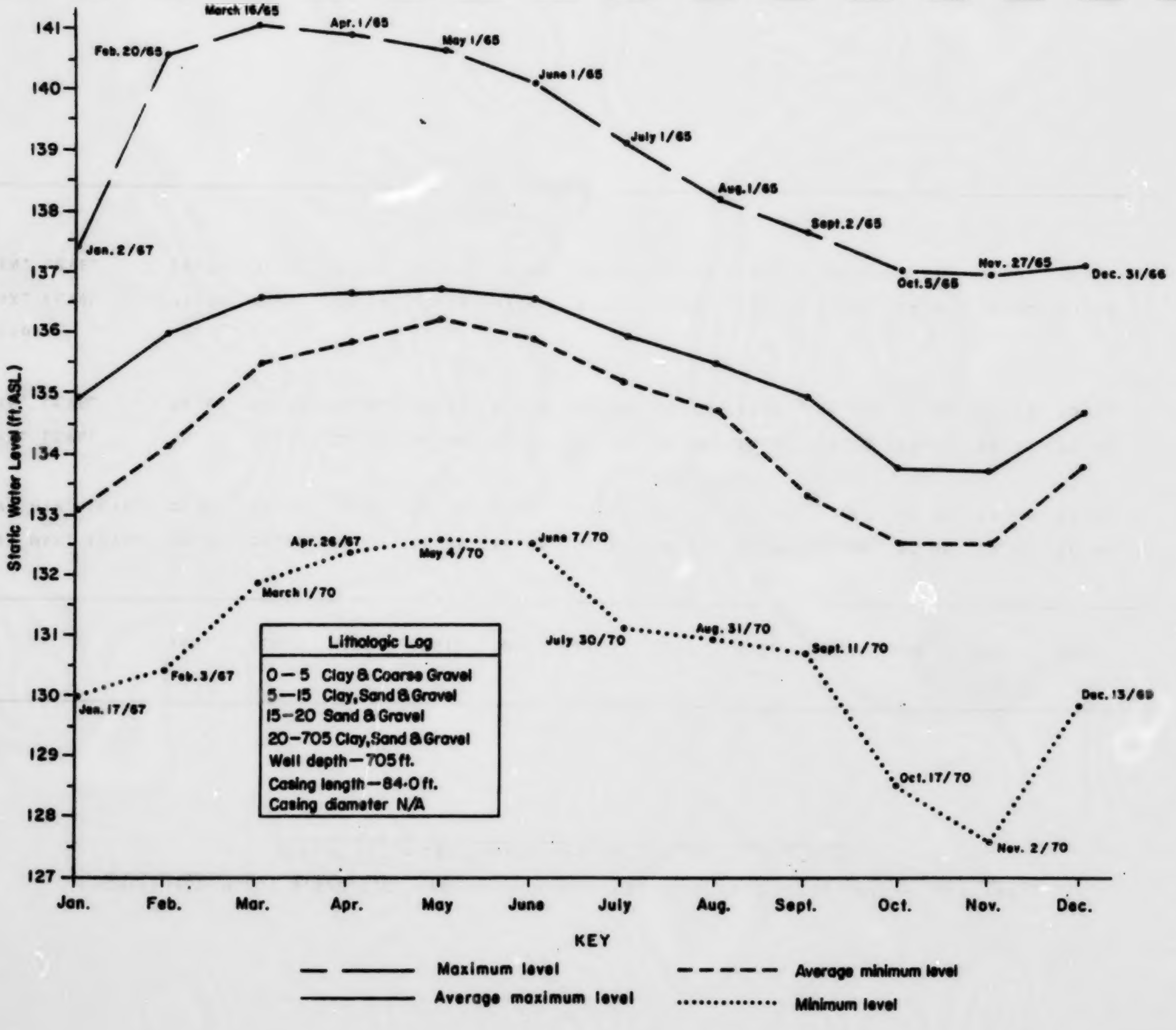


CANNING – N.S.D.O.E. OBSERVATION WELL 031, FEBRUARY 1965 – JULY 1969

BERWICK NSDOE OBSERVATION WELL 032 FEBRUARY, 1965 - AUGUST, 1973

STATIC WATER LEVEL READINGS IN FEET ABOVE SEA LEVEL

	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
AV. MAX. LEVEL	134.93	136.03	136.60	136.69	136.77	136.61	136.03	135.55	135.03	133.83	133.80	134.74
AV. MIN. LEVEL	133.03	134.13	135.52	135.89	136.26	135.96	135.27	134.77	133.35	132.59	132.57	133.89
MAX. LEVEL	137.36	140.62	141.12	140.99	140.71	140.15	139.22	138.77	137.77	137.14	137.06	137.21
MIN. LEVEL	129.95	130.45	131.88	132.47	132.60	132.57	131.16	131.00	130.76	128.06	127.60	129.85
Dates												
MAX. LEVEL	2/67	20/65	16/65	1/65	1/65	1/65	1/65	1/65	2/65	5/65	27/65	31/66
MIN. LEVEL	17/67	3/67	1/70	20/70	4/70	7/70	30/70	31/70	11/70	17/70	2/70	13/69

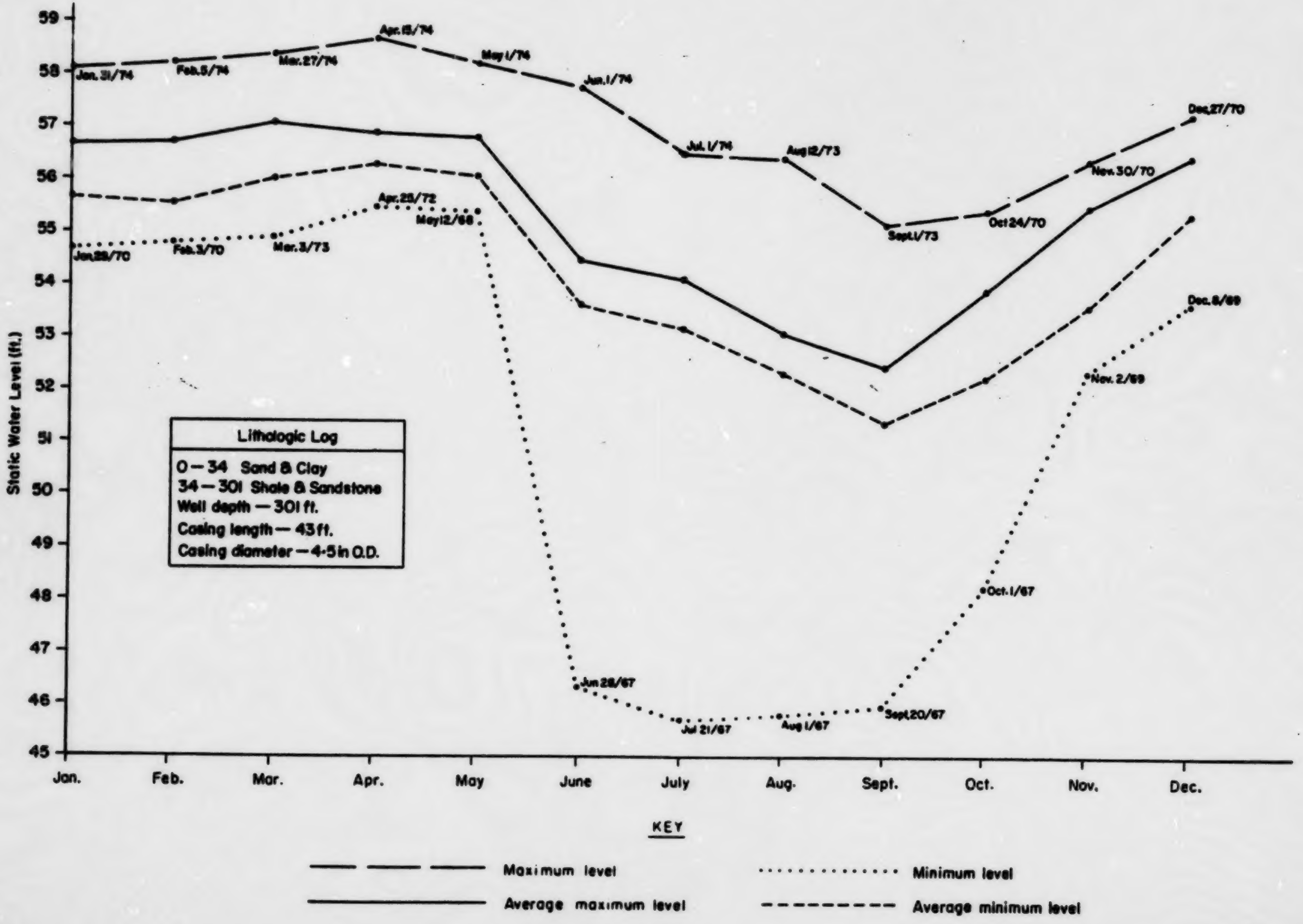


BERWICK- N.S.D.O.E. OBSERVATION WELL 032, FEBRUARY 1965 — AUGUST 1973

SHEFFIELD MILLS N.S.D.O.E. OBSERVATION WELL 033 JUNE 1967-1970, 1972 - JULY 1974

STATIC WATER LEVEL READINGS IN FEET ABOVE SEA LEVEL

	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
AV. MAX. LEVEL	56.72	56.71	57.09	56.98	56.85	54.51	54.14	53.15	52.46	53.94	55.53	56.49
AV. MIN. LEVEL	55.64	55.55	56.01	56.32	56.10	53.67	53.19	52.34	51.41	52.27	53.64	55.40
MAX. LEVEL	58.12	58.23	58.40	58.69	58.25	57.80	56.55	56.45	55.20	55.47	56.46	57.30
MIN. LEVEL	54.68	54.78	54.90	55.50	55.39	46.34	45.72	45.80	46.00	48.30	52.40	53.69
Dates												
MAX. LEVEL	31/74	5/74	27/74	15/74	1/74	1/74	1/74	12/73	1/73	24/70	30/70	27/70
MIN. LEVEL	28/70	3/70	3/73	25/72	12/68	28/67	21/67	1/67	20/67	1/67	2/69	8/69



SHEFFIELD MILLS—N.S.D.O.E. OBSERVATION WELL 033, JUNE 1967–1970, 1972–JULY 1974

APPENDIX C

APPENDIX C

NATIONAL GUIDELINES FOR DESIGNATING WATER QUANTITY SURVEY STATIONS

NATIONAL GUIDELINES FOR DESIGNATING WATER QUANTITY SURVEY STATIONS

These national guidelines of the Federal-Provincial Memoranda of Agreement for Water Quantity Surveys have been prepared by Canada in consultation with the Provinces for the purpose of designating federal, federal-provincial and provincial water quantity survey stations. In compliance with the agreements, the assignment and review of station designations is the responsibility of each Co-ordinating Committee.

The intent of these guidelines is to provide a uniform and consistent manner for designating water quantity survey stations throughout Canada. In these guidelines, "Water quantity survey stations" have the same definition as in the Memoranda of Agreement and include water level, streamflow and sediment survey stations. The word "stations" in these guidelines means "water quantity survey stations". Where not otherwise specified, the word "Province" or "Territory". The designation of each sediment station can be considered separately from the corresponding water quantity survey station designation.

FEDERAL STATIONS

These are stations that support programs of primary interest to the Government of Canada. These stations are funded 100 per cent by

Canada in accordance with Article II and the procedures described in Schedules B, C and D (F for the Yukon) (and Schedules E, D and F for Quebec) of the Memorandum of Agreement.

1. Federal Departmental Programs

These are stations required under statutory obligations that have developed in response to federal legislation and priorities, and as a result of programs of various federal government departments or agencies to provide quantity information on inland waters. These include stations operated in support of specific federal works, benchmark basins, studies or investigations, research projects and to meet navigational requirements and management responsibilities. A station may be so designated where Canada has formally accepted responsibility for the continued operation of the station under an implementation agreement.

2. Interprovincial Waters

These are stations required for monitoring of waters flowing across or forming part of provincial or territorial boundaries where federal responsibility has been established by an agreement or where justified by an inter-jurisdictional concern.

3. International Waters

These are stations associated with federal responsibilities arising from international agreements, treaties, orders or studies. These include:

a) Stations specifically named under the Boundary Waters Treaty and those approved officially as "International Gauging Stations".

b) Stations specifically stipulated under IJC orders, or required to support such orders; to provide for control of waters corssing or forming part of the international boundaryand for IJC related study, surveillance, flow regulation or apportionment purposes. Such stations may also be required for similar studies carried out under unilateral or bilateral mechanisms and undertaken in anticipation of the need for formal orders.

c) Stations related to international treaties and agreements which involve waters crossing or forming part of the internatinal boundary and which specifically stipulate the reaches of streams required to be monitored or special arrangements that need to be made to meet water quantity survey needs.

d) Stations on streams flowing across or forming part of the international boundary for which Canada has determined that monitoring is required for water management purposes.

4. National Water Quantity Inventory

These are stations that provide information for a national inventory of surface waters. They consist of those stations required to determine water quantity trends in the major drainage basins in Canada that serve to provide an assessment of the total surface water resources and to measure significant discharge to the oceans.

FEDERAL-PROVINCIAL AND/OR FEDERAL-TERRITORIAL STATIONS

These are stations that support programs of joint interest to Canada and the Province. The construction and operation of these stations are funded in accordance with Article III and procedures described in Schedules B, C and D (F for the Yukon) and (Schedules E, D and F for Quebec) of the Memoranda of Agreement.

1. Federal-Provincial Agreements

These are stations where joint federal and provincial (or territorial) responsibility is established under the terms and conditions of an agreement between Canada and one or more Provinces or Territories.

The joint funding arrangements for any particular agreement must be taken into consideration before designating a station in order to ensure the intended division of financial responsibility. Following the completion of a federal-provincial water study, a station may be designated in this category only if its continuation would be in the joint interest of Canada and the Province.

2. River Basin Management

These are stations where both Canada and the Province have stated an interest in the need for information to support the management of the water resources of a river basin.

3. Regional Water Quantity Inventory

These are stations that provide an assessment of the quantity of water resources available in district hydrologic zones within each Province through representative sampling taking into consideration climaticvariability, geographic and geologic differences, levels of population and development, basin size, streamflow regime, relationship to major ground water resources and length of record.

PROVINCIAL AND/OR TERRITORIAL STATIONS

These are stations that support programs of primary interest to a Province. They are funded 100 per cent by the Province in accordance with Article IV and procedures described in Schedules B, C and D (F for the Yukon) (and Schedules E, D and F for Quebec) of the Memoranda of Agreement.

1. Provincial Departmental Programs

These are stations required strictly for provincial programs where water quantity information on inland waters is needed.

2. Specific Purpose Monitoring Requirements

These restations established as a result of specific requests of provincial/territorial agencies, municipalities or non-government organizations. All such requests shall be referred to the Province for screening and funding arrangements before being presented to the applicable Coordinating Committee.

APPENDIX D

Appendix D

Theoretical Development of Uncertainty Functions

Uncertainty in streamflow records is measured in this study as the variance of estimation of instantaneous discharges. The accuracy of a streamflow estimate depends on how that estimate was obtained. Three situations are considered: (1) streamflow is estimated from observed stage data using the stage-discharge (rating curve) relation which is subject to error, (2) streamflow is reconstructed using data from nearby sites because observed stage data are missing, and (3) streamflow is estimated from the expected value of discharge for the period of missing record. The variances of the estimates of streamflow that would be employed in each situation was weighted by the fraction of time each situation is expected to occur. Thus the total estimation variance would be

$$V_T = e_f V_f + e_r V_r + e_e V_e \tag{D1}$$

with

$$1 = e_f + e_r + e_e$$

where

V_T is the expected total error variance of the streamflow estimates,

e_f is the fraction of time that the stage recorders are functioning,

V_f is the variance of flow estimates when the stage recorders are working,

e_r is the fraction of time that secondary data are available to reconstruct streamflow records given that the stage data are missing,

V_r is the variance of flows reconstructed from secondary data,

e_e is the fraction of time that stage and secondary data are not available to compute streamflow records, and

V_e is the variance of the third situation.

The fractions of time that each source of error is relevant are functions of the frequencies at which the recording equipment is serviced.

The time t since the last service visit until failure of the stage recorder or recorders at the site is assumed to have a negative-exponential probability distribution truncated at the next service time; the distribution's probabiity density function is

$$f(t) = ke^{-k\ t} /(1-e^{-ks}) \tag{D2}$$

where

k is the average time to failure in units of $(\text{day})^{-1}$,

e is the base of natural logarithms, and

s is the interval between visits to the site in days.

It is assumed that, if a recorder fails,it continues to malfunction until the next service visit. Thus the fraction of time, e_f, that the recorder can be expected to operate properly is

$$e_f = 1 - E[d]/s \tag{D3}$$

where E [.] is the expected value of the random variable contained in the brackets and d is the downtime of the recorder between visits. Downtime is defined

$$d = \begin{cases} s - t & \text{if a failure occurs,} \\ 0 & \text{if no failure occurs} \end{cases} \tag{D4}$$

as is shown in figure D1. The expected value of the downtime, E[d], can be evaluated using equation D2 and results in the following equation

$$E[d] = (ks + e^{-ks} - 1)/k. \tag{D5}$$

Substituting equation D5 into equation D3 and simplifying results in

$$e_f = (1 - e^{-ks})/ks \tag{D6}$$

In application k, the average time to failure, is determined from equation D6 by substituting values for s, the service interval, and e_f, the fraction of time the recorder is working. The values of s and e_f are determined for a known visitation frequency by analyzing the lost stage record. Once k is determined for given values of s and e_f, then e_f can be determined for any desired visitation frequency. The fraction of time e_e that no records exist at either the site of interest or a nearby site can also be derived assuming that the time between failures at both sites are independent and have negative exponential distributions with the same rate constant. It then follows that

$$e_e = 1 - [2(1 - e^{-ks}) + 0.5(1 - e^{-2ks})]/(ks) \tag{D7}$$

FIGURE D 1

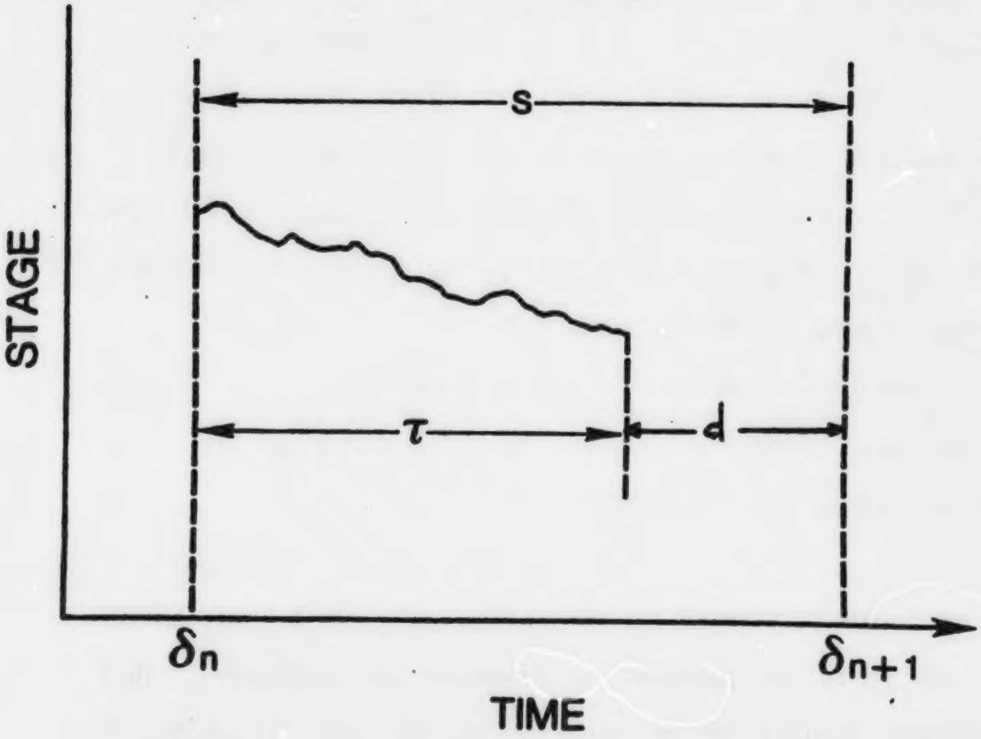
τ = Time to failure

s = Service interval

d = Down time (missing stage record)

$d = s - \tau$

δ_n = Time of the nth visit


s
STAGE
τ
d
δ_n
δ_{n+1}
TIME

Definition of downtime for a single station.

Finally, the fraction of time e_r that records are reconstructed based on data from a secondary site is determined by the equation

$$e_r = 1 - e_f - e_e \qquad \text{(D8)}$$

$$= [(1-e^{-ks}) + 0.5((1-e^{-2ks})]/(ks)$$

The variance, V_f, of the error derived from the rating curve is determined by analyzing a time series of residuals that are the differences between the logarithms (in this application using base 10) of measured discharge and the rating curve discharge. The rating curve discharge is determined from a relationship between discharge and some correlative data, usually water-surface elevation (stage) for the gauging station. The measured discharge ($q_m(t)$ is the discharge determined by field observations of depths, widths, and velocities. Let $q_T(t)$ be the true instantaneous discharge at time t and let $q_R(t)$ be the value that would be estimated using the rating curve. Then

$$x(t) = \log q_T(t) - \log q_R(t) = \log [q_T(t)/q_R(t)] \qquad \text{(D9)}$$

is the instantaneous difference between the logarithms of the true discharge and the rating curve discharge.

In computing estimates of streamflow, the rating curve may be continually adjusted on the basis of periodic measurements of discharge. This adjustment process results in an estimate, $q_c(t)$, that is a better estimate of the stream's discharge at time t. The difference between the variable x(t), which is defined

$$x(t) = \log q_c(t) - \log q_R(t) \tag{D10}$$

and x(t) is the error in the streamflow record at time t. The variance of this difference over time is the desired estimate of V_f.

Unfortunately, the true instantaneous discharge $q_T(t)$ cannot be determined so that the values of x(t) and the difference, x(t) - x(t), can never be determined. However, the statistical properties of x(t) - x(t), particularly its variance, can be inferred from the available discharge measurements. Let the observed residuals be z(t) so that

$$z(t) = x(t) + v(t) = \log q_m(t) - \log q_R(t) \tag{D11}$$

where

v(t) is the measurement error, and

$\log q_m(t)$ is the logarithm of the measured discharge equal to $\log q_T(t)$ plus v(t).

In the Kalman-filter analysis, the z(t) time series was analyzed to determine three site-specific parameters. The Kalman filter used in this study assumes that the time residuals x(t) arise from a continuous first-order Markovian process that has a Gaussian (normal) probability distribution with zero mean and variance (subsequently referred to as process variance) equal to p. The process variance is the variability about the rating curve assuming no error in the discharge measurements. A second important parameter is β , the reciprocal of the correlation time of the Markovian process giving rise to $x(t)$; the correlation between $x(t_1)$ and $x(t_2)$ at $| t_1-t_2 |$ days apart is $\exp[-\beta | t_1-t_2 |]$. The one-day auto correlation coefficient (RHO) is defined as $\exp[-\beta]$. Fontaine and others (1984) also define q, the constant value of the spectral density function of the white noise which drives the Gauss-Markov x-process. The parameters, p, q, and β are related by

$$\mathrm{Var}[x(t)] = p = q/2\beta) \tag{D12}$$

The variance of the observed residuals $z(t)$ is

$$\mathrm{Var}[z(t)] = p + r \tag{D13}$$

where r is the variance of the measurement error $v(t)$. The three parameters, p, β, and r, are computed by analyzing the statistical properties of the $z(t)$ time series. These three site-specific parameters are needed to define this component of the uncertainty relationship. The Kalman filter utilizes these three parameters to determine the variance of the errors of discharges estimated from the rating curve (V_f) as a function of the number of discharge measurements per year (Moss and Gilroy, 1980). For example, if only one measurement $qm(t_1)$ and residual $z(t_1)$ were available at time t_1, then the optimal estimator of the true residual $x(t)$ at any future time t would be

$$x(t) = z(t_1)\, e^{-\beta | t_1-t |} / (1+r/p) \tag{D14}$$

where the resultant variance of the actual flow estimates satisfies

$$\ln [1+V_f] = p[1 - e^{-2\beta | t_1-t |} / (1+r/p)] \tag{D15}$$

When a sequence of residuals $z(t_i)$ are available, closed form expressions for $\dot{x}(t)$ and the error variances are quite complex. However, a Kalman filter can be used to calculate the optimal linear smoother (Gelb, 1974, Chapter 5) which provides the required numerical values (Moss and Gilroy, 1980).

If the recorder at the site of interest fails and there is no concurrent data at other nearby sites that can be used to reconstruct the missing record, there are two ways of estimating discharges at the site of interest. A recession curve could be applied from the time of recorder stoppage until the gauge was once again functioning or the expected value of discharge for the period of missing data could be used as an estimate. The expected-value approach is used in this study to estimate V_e, the error variance during periods of no concurrent data at nearby sites. If the expected value is used to estimate discharge, the value that is used should be the expected value of discharge at the time of year of the missing record because of the seasonality of the streamflow processes. The variance of streamflow, which also is a seasonally varying parameter, is an estimate of the error variance that results from using the expected value as an estimate. Thus the coefficient of variation squared $(C_v)^2$ is an estimate of the required error variance V_e. Because C_v varies seasonally and the times of failures cannot be anticipated, a seasonally averaged value of C_v is used:

$$\bar{C}_v = \left[\frac{1}{365} \sum_{i=1}^{365} \left(\frac{Si}{mi} \right)^2 \right]^{1/2} \qquad \text{(D16)}$$

where

s_i is the standard deviation of daily discharges for the i^{th} day of the year, and

m_i is the expected value of discharge on the i^{th} day of the year.

$(\overline{C}_v)^2$ is used as an estimate of V_e.

The variance V_r of the error during periods of reconstructed streamflow records is estimated on the basis of correlation between daily mean discharges at the site of interest and daily mean discharges from other nearby sites. The correlation coefficient (CROSS) between the streamflows with seasonal trends removed at the site of interest and detrended streamflows at the other sites is a measure of the goodness of their linear relationship. The fraction of the variance of streamflow at the site of interest that is explained by data from the other sites is equal to $(\mathrm{CROSS})^2$. Thus the error variance of flow estimates at the site of interest obtained from secondary information will be

$$V_r = (1-(\mathrm{CROSS})^2)\,(\overline{C}_v)^2 \tag{D17}$$

Because errors in streamflow estimates arise from three different sources with widely varying precisions, the resultant distribution of those errors may differ significantly from a normal or lognormal distribution. This lack of normality causes difficulty in interpretation of the resulting total estimation variance. When stage and secondary data are unavailable, the error variance V_e may be very large. This could yield correspondingly large values of V_T in equation (D1) even if the probability that stage and secondary data are not available, e_e, is quite small (say 10^{-3}).

A new parameter, the equivalent Gaussian spread (EGS), is introduced here to assist in interpreting the results of the analyses. Assuming that the various errors arising from the three situations represented in equation (D1) are lognormally distributed, the value of EGS was determined by the probability statment that

$$\Pr\left[e^{-EGS} \leq q_m(t) / q_T(t) \leq e^{+EGS}\right] = 0.683 \qquad \text{(D18)}$$

Thus, if the residuals $\log q_m(t) - \log q_T(t)$ were normally distributed, $(EGS)^2$ would be their variance. Here EGS is reported in units of percent because EGS is defined so that nearly two-thirds of the errors in instantaneous streamflow data will be within plus or minus EGS percent of the reported values.

HYDROLOGIC NETWORK REVIEW

NOVA SCOTIA

APPENDIX "E"

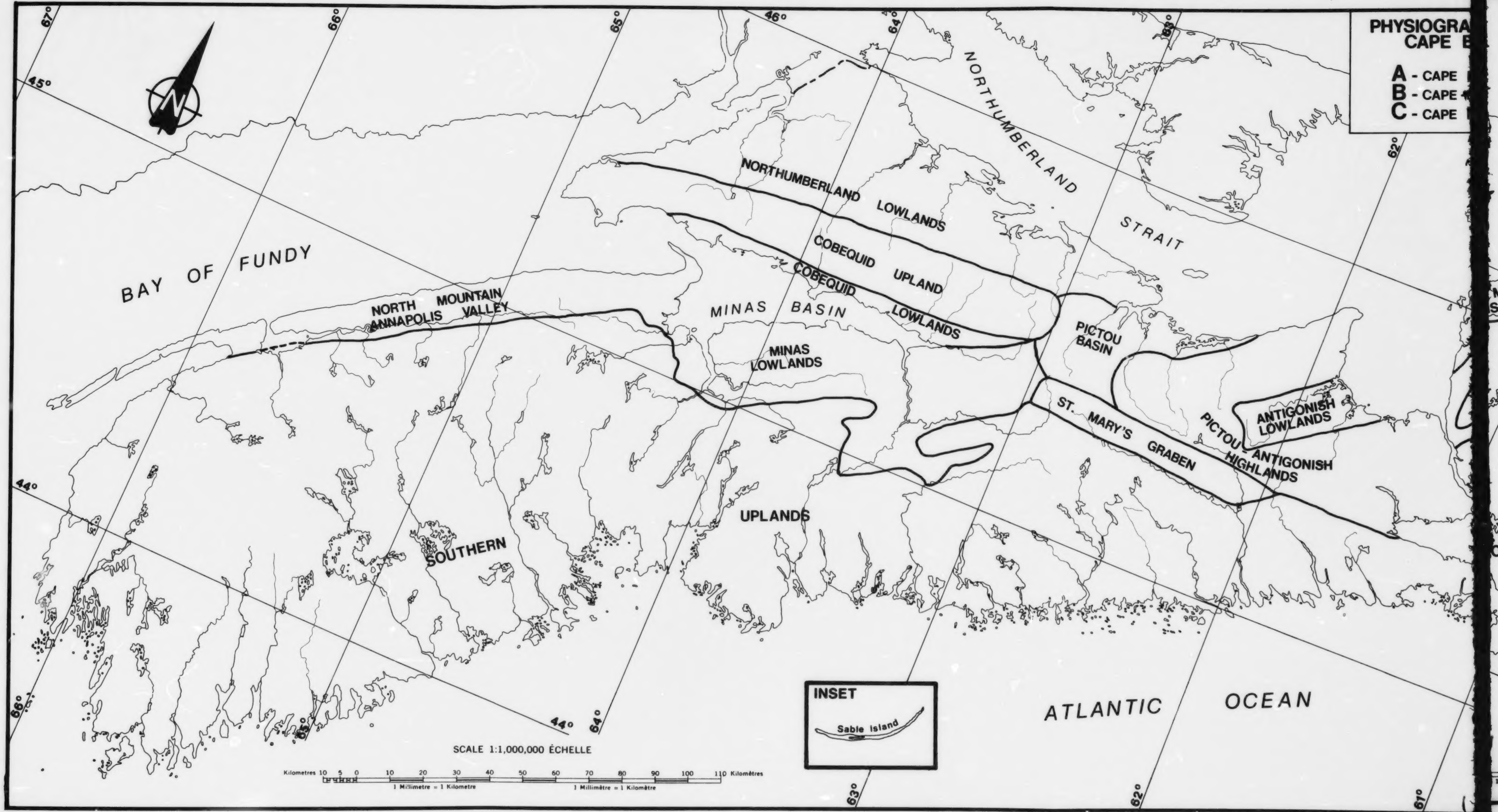
(MAPS)

JOINTLY PREPARED BY

Environment
Canada

Department of the
Environment

Halifax 1985


PHYSIOGRA
CAPE B
A - CAPE
B - CAPE
C - CAPE
BAY OF FUNDY
NORTHUMBERLAND STRAIT
NORTHUMBERLAND LOWLANDS
COBEQUID UPLAND
COBEQUID LOWLANDS
NORTH MOUNTAIN
ANNAPOLIS VALLEY
MINAS BASIN
MINAS LOWLANDS
PICTOU BASIN
ST. MARY'S GRABEN
ANTIGONISH LOWLANDS
PICTOU - ANTIGONISH HIGHLANDS
SOUTHERN UPLANDS
ATLANTIC OCEAN
INSET
Sable Island
SCALE 1:1,000,000 ÉCHELLE
Kilometres 10 5 0 10 20 30 40 50 60 70 80 90 100 110 Kilomètres
1 Millimetre = 1 Kilometre
1 Millimètre = 1 Kilomètre
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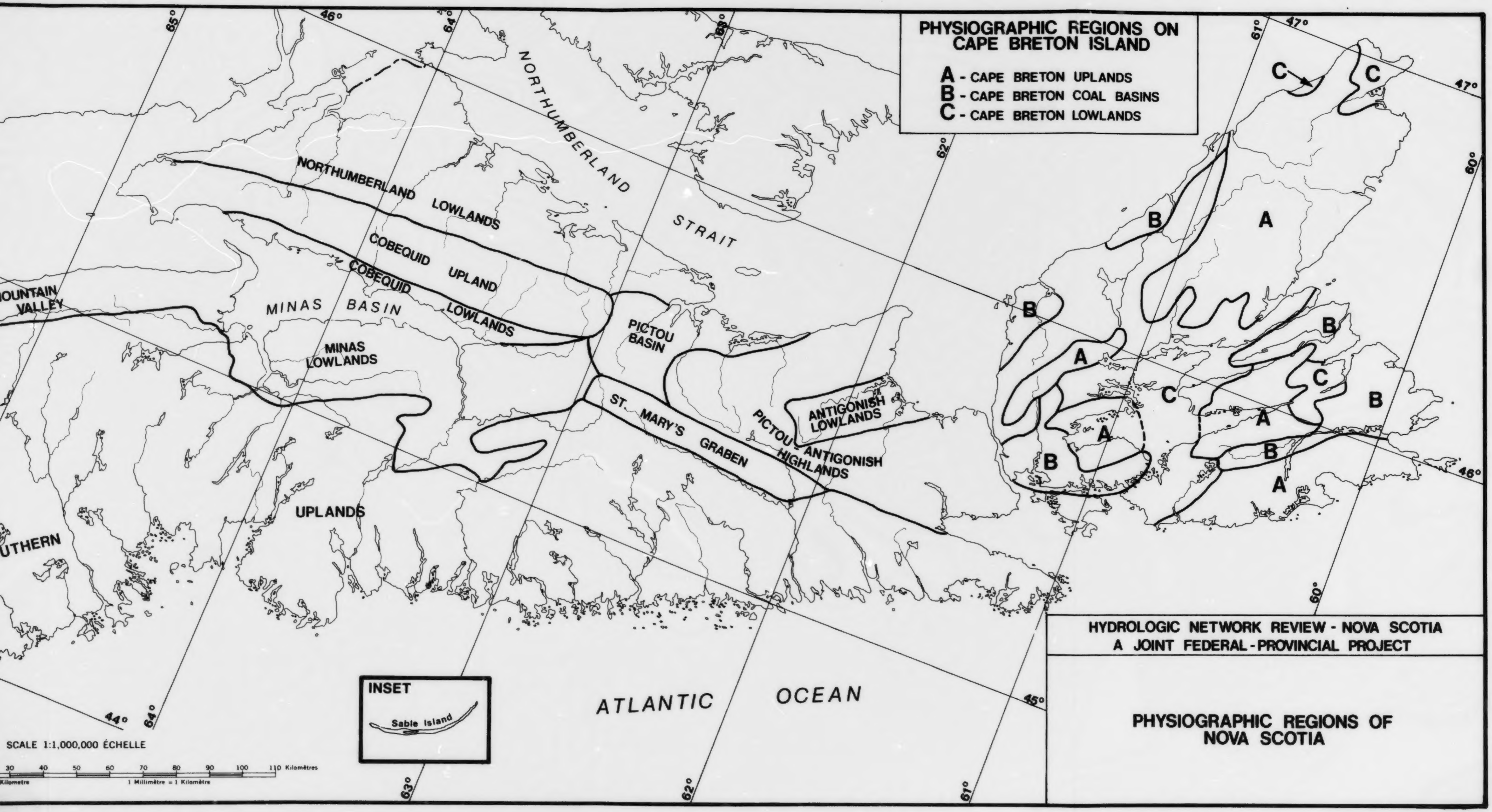
PHYSIOGRAPHIC REGIONS ON CAPE BRETON ISLAND
A - CAPE BRETON UPLANDS
B - CAPE BRETON COAL BASINS
C - CAPE BRETON LOWLANDS
NORTHUMBERLAND STRAIT
NORTHUMBERLAND LOWLANDS
COBEQUID UPLAND
COBEQUID LOWLANDS
MINAS BASIN
MINAS LOWLANDS
OUNTAIN VALLEY
PICTOU BASIN
ST. MARY'S GRABEN
ANTIGONISH LOWLANDS
PICTOU - ANTIGONISH HIGHLANDS
UPLANDS
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ATLANTIC OCEAN
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SCALE 1:1,000,000 ÉCHELLE
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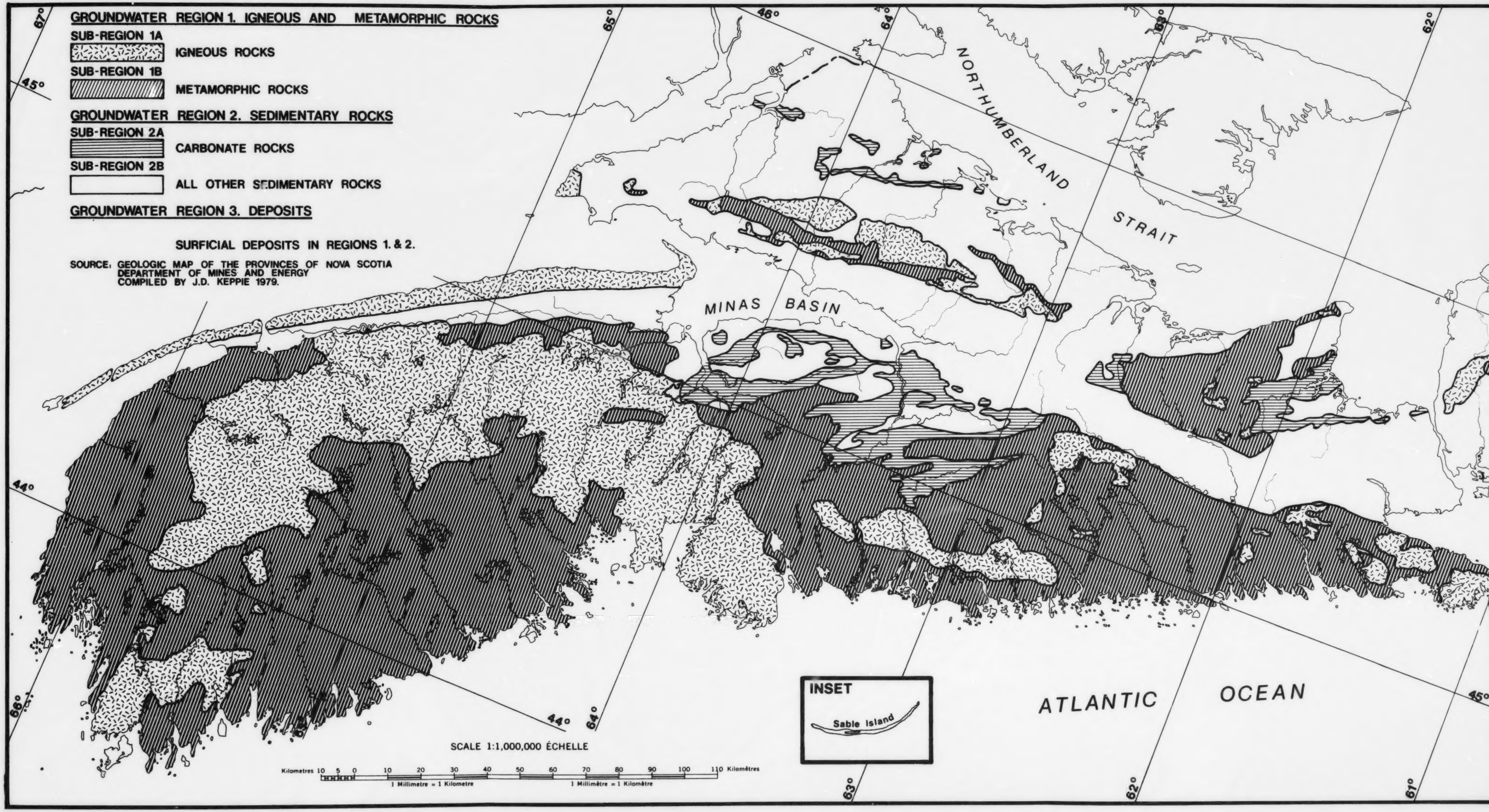
Kilometre
1 Millimètre = 1 Kilomètre

HYDROLOGIC NETWORK REVIEW - NOVA SCOTIA
A JOINT FEDERAL-PROVINCIAL PROJECT

PHYSIOGRAPHIC REGIONS OF NOVA SCOTIA

APPENDIX E-1


GROUNDWATER REGION 1. IGNEOUS AND METAMORPHIC ROCKS
SUB-REGION 1A
IGNEOUS ROCKS
SUB-REGION 1B
METAMORPHIC ROCKS
GROUNDWATER REGION 2. SEDIMENTARY ROCKS
SUB-REGION 2A
CARBONATE ROCKS
SUB-REGION 2B
ALL OTHER SEDIMENTARY ROCKS
GROUNDWATER REGION 3. DEPOSITS
SURFICIAL DEPOSITS IN REGIONS 1. & 2.
67°
45°
65°
46°
64°
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62°
NORTHUMBERLAND
STRAIT
MINAS BASIN
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ATLANTIC
OCEAN
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INSET
Sable Island
SCALE 1:1,000,000 ÉCHELLE
Kilometres 10 5 0 10 20 30 40 50 60 70 80 90 100 110 Kilomètres
1 Millimetre = 1 Kilometre
1 Millimètre = 1 Kilomètre
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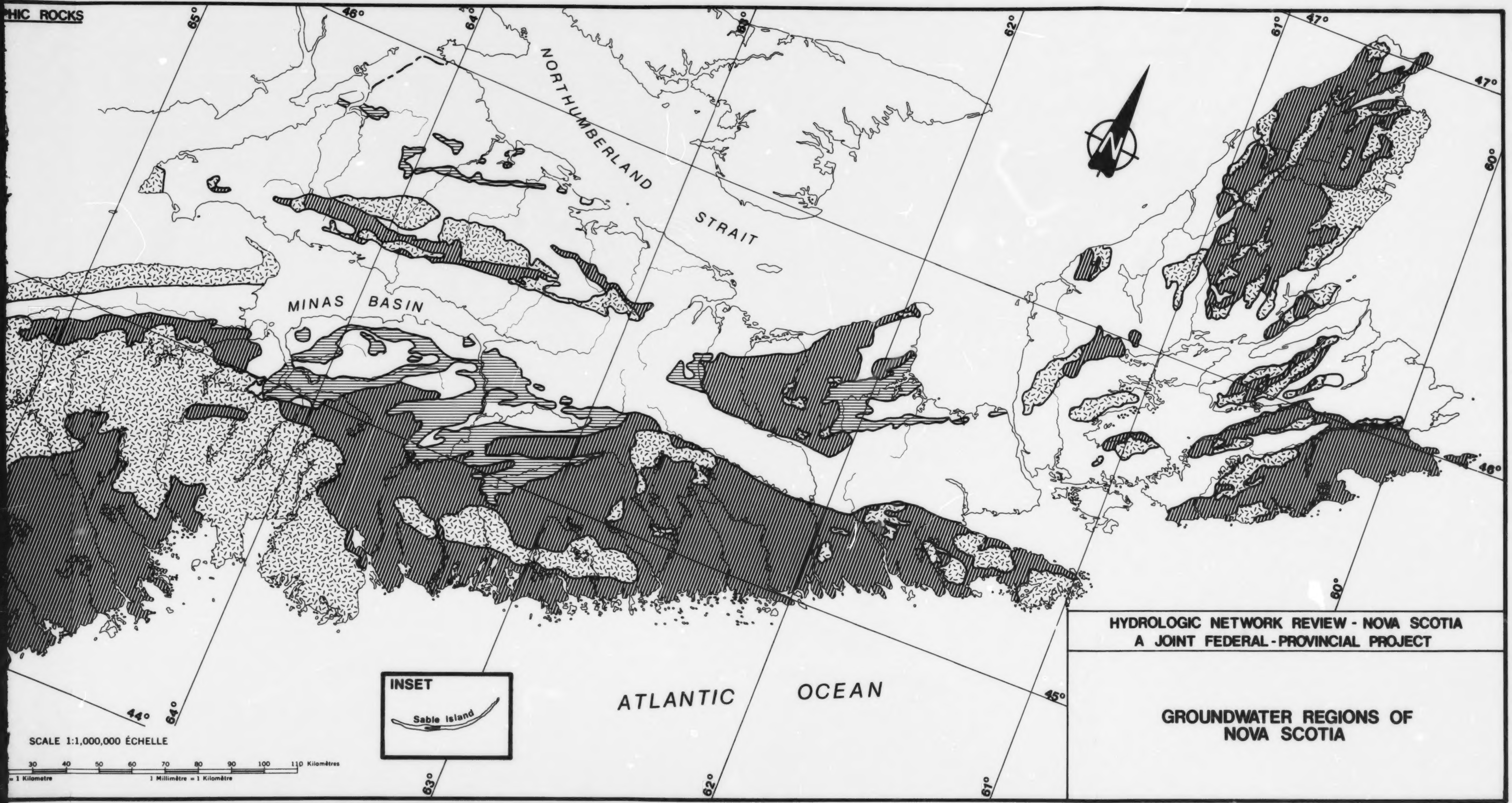
SOURCE: GEOLOGIC MAP OF THE PROVINCES OF NOVA SCOTIA
DEPARTMENT OF MINES AND ENERGY
COMPILED BY J.D. KEPPIE 1979.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SCALE 1:1,000,000 ÉCHELLE
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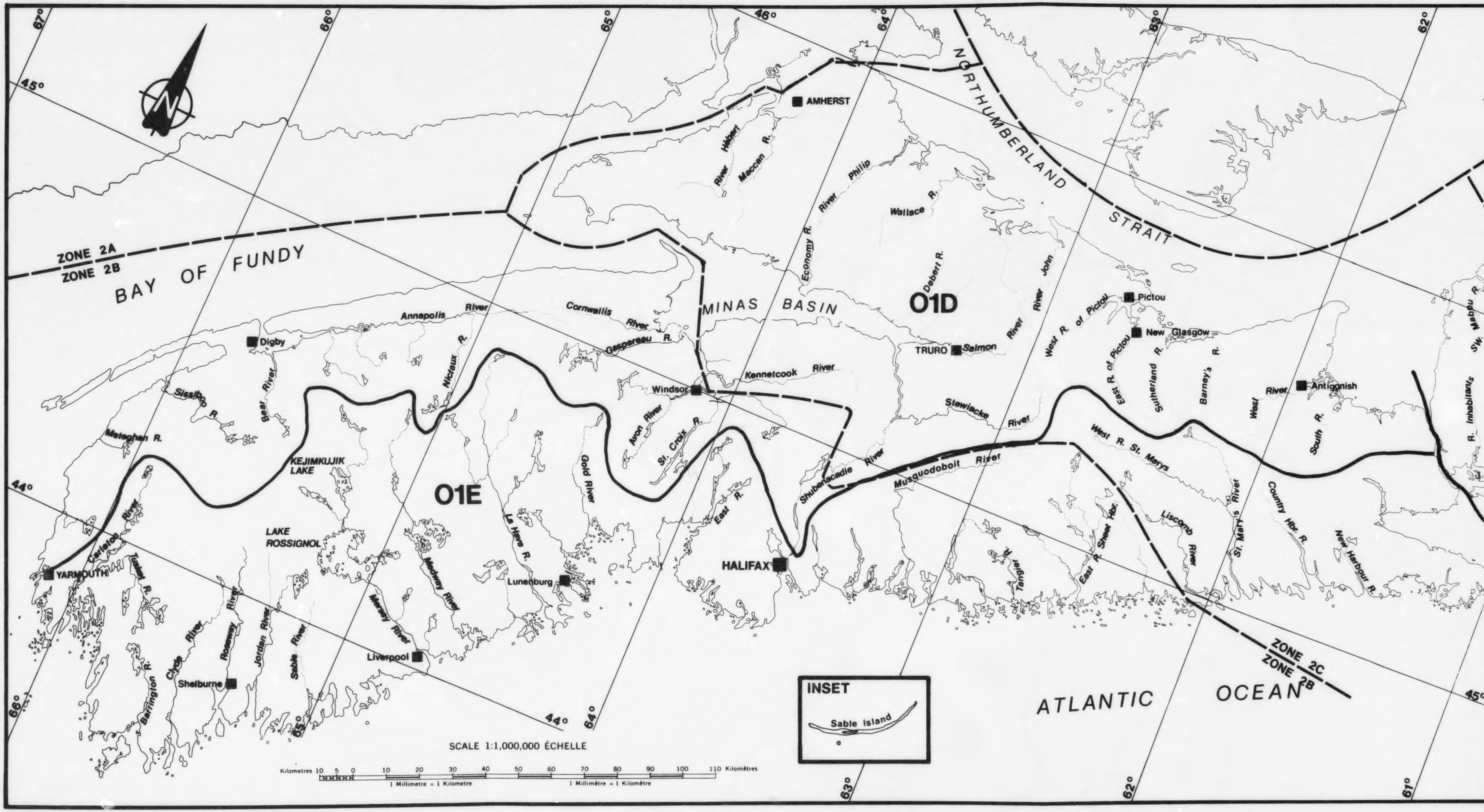
HYDROLOGIC NETWORK REVIEW - NOVA SCOTIA
A JOINT FEDERAL-PROVINCIAL PROJECT
GROUNDWATER REGIONS OF NOVA SCOTIA

APPENDIX E-2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ZONE 2B
ZONE 2C
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NORTHUMBERLAND STRAIT
MINAS BASIN
ATLANTIC OCEAN
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O1E
AMHERST
Hébert River
Maccan R.
River Philip
Wallace R.
Economy R.
Debert R.
River John
Salmon River
TRURO
Pictou
New Glasgow
West R. of Pictou
East R. of Pictou
Sutherland R.
Barney's R.
West River
Antigonish
South R.
SW. Mabou R.
R. Inhabitants
Stewiacke River
Kennetcook River
Windsor
Avon River
St. Croix R.
Cornwallis River
Gaspereau R.
Annapolis River
Digby
Nictaux R.
Bear River
Sissiboo R.
Meteghan R.
KEJIMKUJIK LAKE
LAKE ROSSIGNOL
Gold River
La Have R.
Medway River
Mersey River
Lunenburg
Liverpool
Sable River
Jordan River
Roseway River
Clyde River
Barrington R.
Tusket R.
Carleton River
YARMOUTH
Shelburne
HALIFAX
East R.
Shubenacadie River
Musquodoboit River
Tangier R.
East R. Sheet Hbr.
West R. St. Marys
Liscomb River
St. Mary's River
Country Hbr. R.
New Harbour R.
INSET
Sable Island
SCALE 1:1,000,000 ÉCHELLE
Kilometres 10 5 0 10 20 30 40 50 60 70 80 90 100 110 Kilomètres
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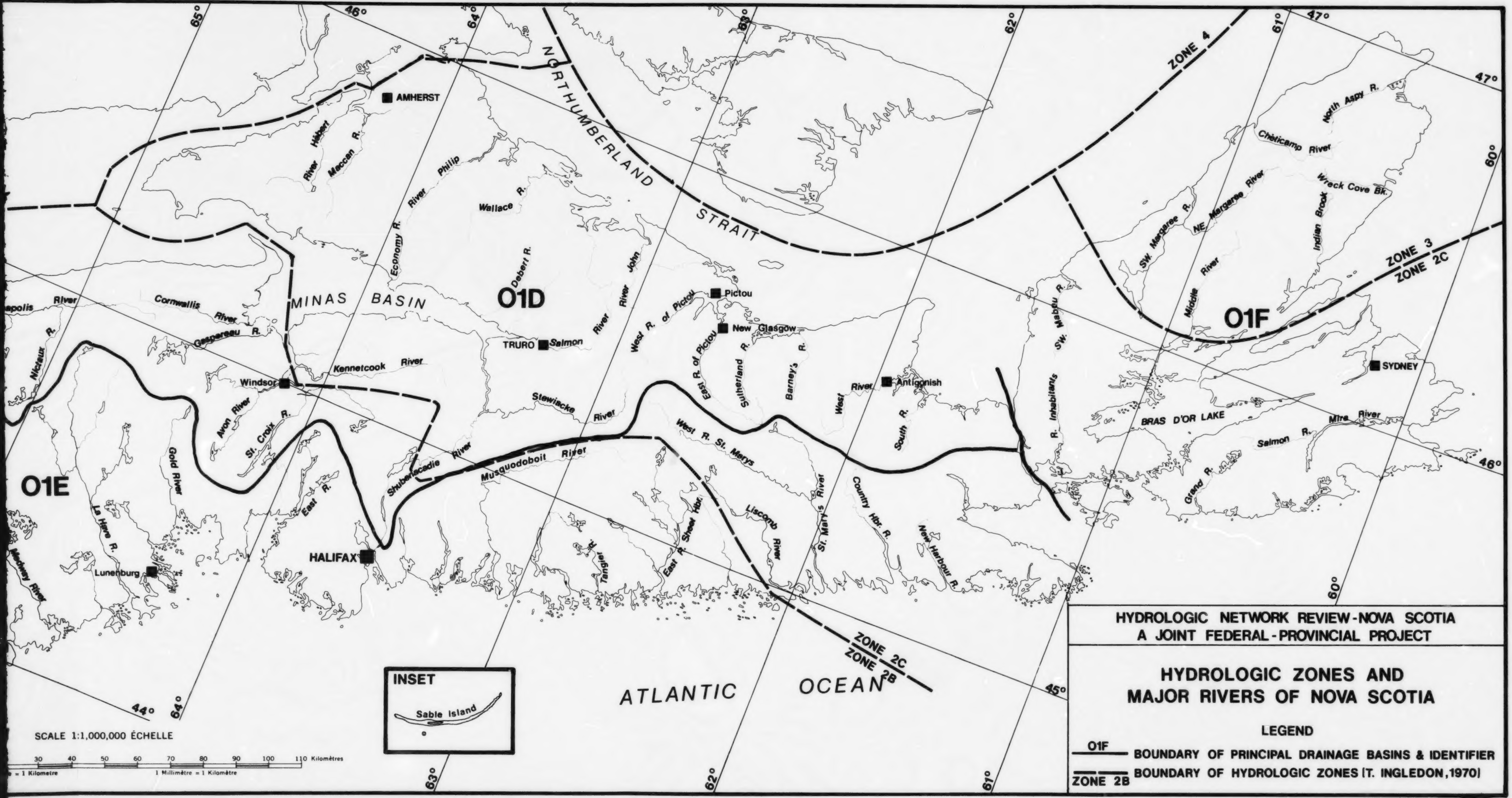
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NORTHUMBERLAND STRAIT
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ZONE 3
ZONE 2C
ZONE 2C
ZONE 2B
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River Hébert
Maccan R.
River Philip
Wallace R.
Economy R.
Debert R.
River John
O1D
MINAS BASIN
Cornwallis River
apolis River
Nictaux R.
Gaspereau R.
Kennetcook River
Windsor
Avon River
St. Croix R.
TRURO
Salmon River
Stewiacke River
Shubenacadie River
Musquodoboit River
West R. of Pictou
East R. of Pictou
Pictou
New Glasgow
Sutherland R.
Barney's R.
West River
Antigonish
South R.
West R. St. Marys
St. Mary's River
Liscomb River
Country Hbr. R.
New Harbour R.
East R. Sheet Hbr.
Tangier R.
East R.
HALIFAX
Gold River
La Have R.
Lunenburg
Medway River
O1E
R. Inhabitants
SW. Mabou R.
SW. Margaree R.
NE Margaree River
Middle River
Chéticamp River
North Aspy R.
Wreck Cove Bk.
Indian Brook
O1F
SYDNEY
BRAS D'OR LAKE
Salmon R.
Mira River
Grand R.
ATLANTIC OCEAN
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SCALE 1:1,000,000 ÉCHELLE
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1 Millimètre = 1 Kilomètre

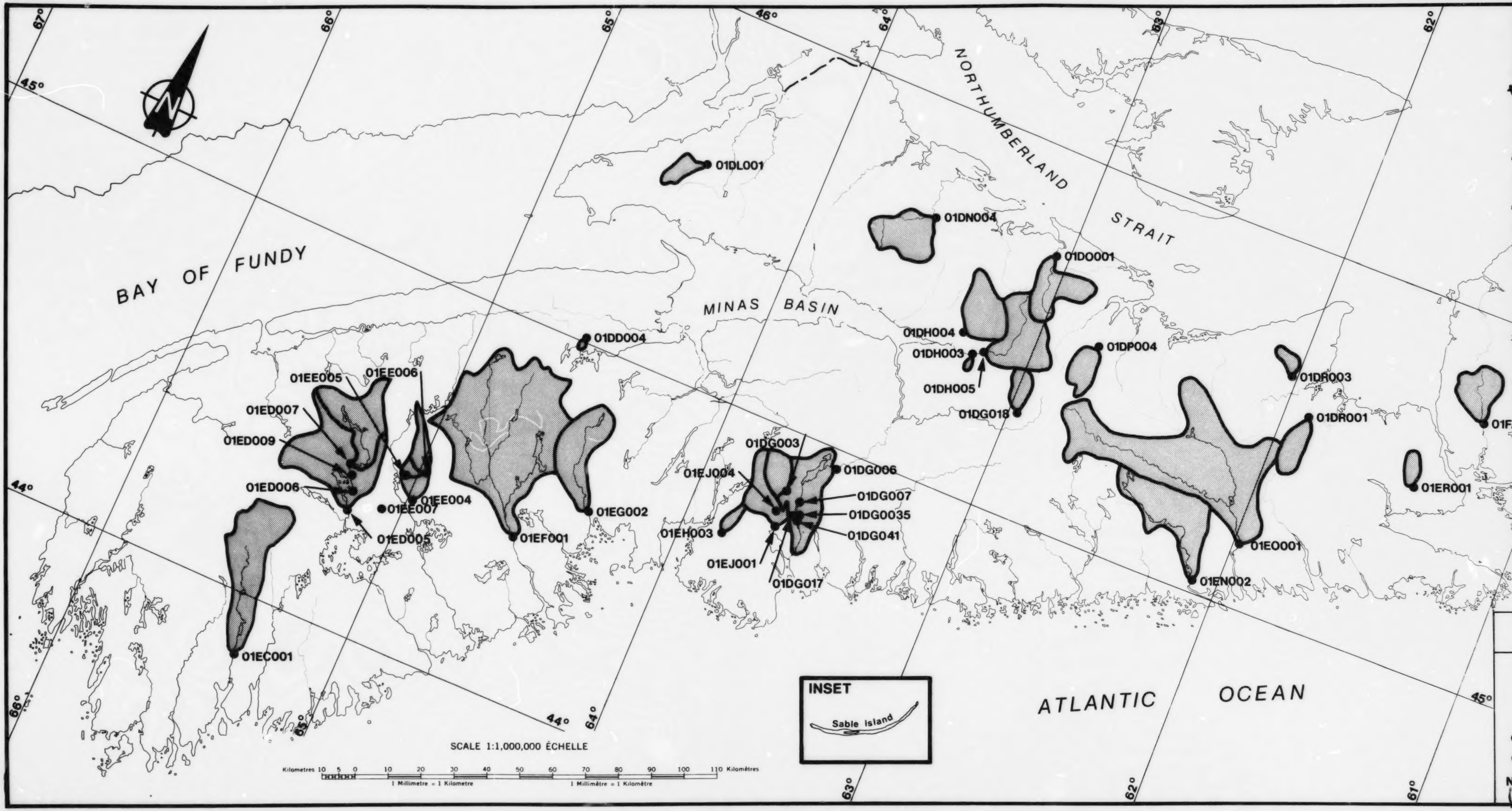
HYDROLOGIC NETWORK REVIEW-NOVA SCOTIA
A JOINT FEDERAL-PROVINCIAL PROJECT

HYDROLOGIC ZONES AND MAJOR RIVERS OF NOVA SCOTIA

LEGEND

O1F BOUNDARY OF PRINCIPAL DRAINAGE BASINS & IDENTIFIER

ZONE 2B BOUNDARY OF HYDROLOGIC ZONES [T. INGLEDON, 1970]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MINAS BASIN
NORTHUMBERLAND STRAIT
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01DH004
01DH003
01DH005
01DG018
01DP004
01DR003
01DR001
01ER001
01F
01DD004
01EE005
01EE006
01ED007
01ED009
01ED006
01EE007
01EE004
01ED005
01EF001
01EG002
01EC001
01DG003
01EJ004
01DG006
01DG007
01DG0035
01DG041
01EH003
01EJ001
01DG017
01EO001
01EN002
INSET
Sable Island
SCALE 1:1,000,000 ÉCHELLE
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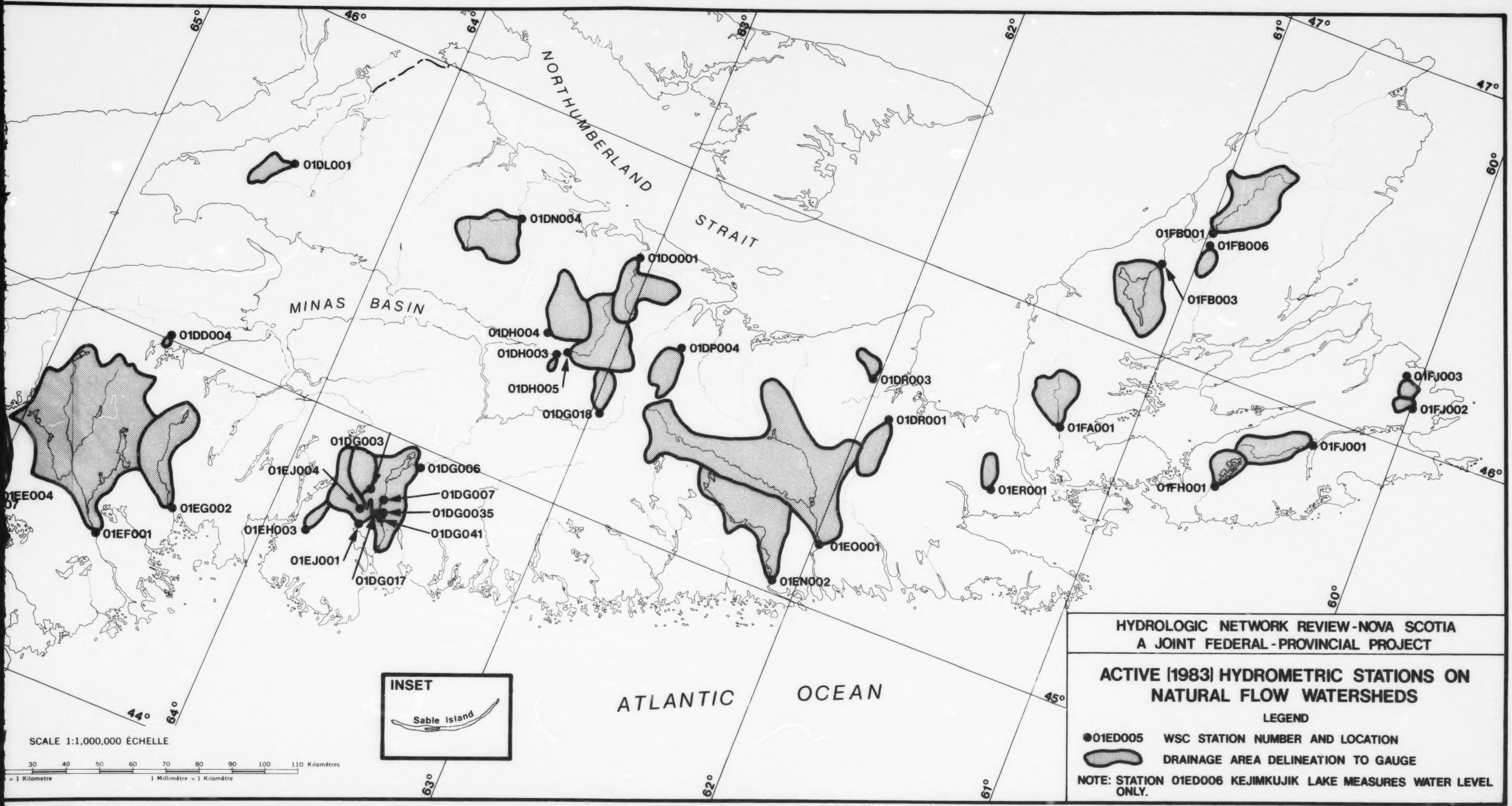
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01DP004
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01EG002
01DG003
01EJ004
01DG006
01DG007
01DG0035
01DG041
01EH003
01EJ001
01DG017
01DR003
01DR001
01EO001
01EN002
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HYDROLOGIC NETWORK REVIEW - NOVA SCOTIA
A JOINT FEDERAL - PROVINCIAL PROJECT

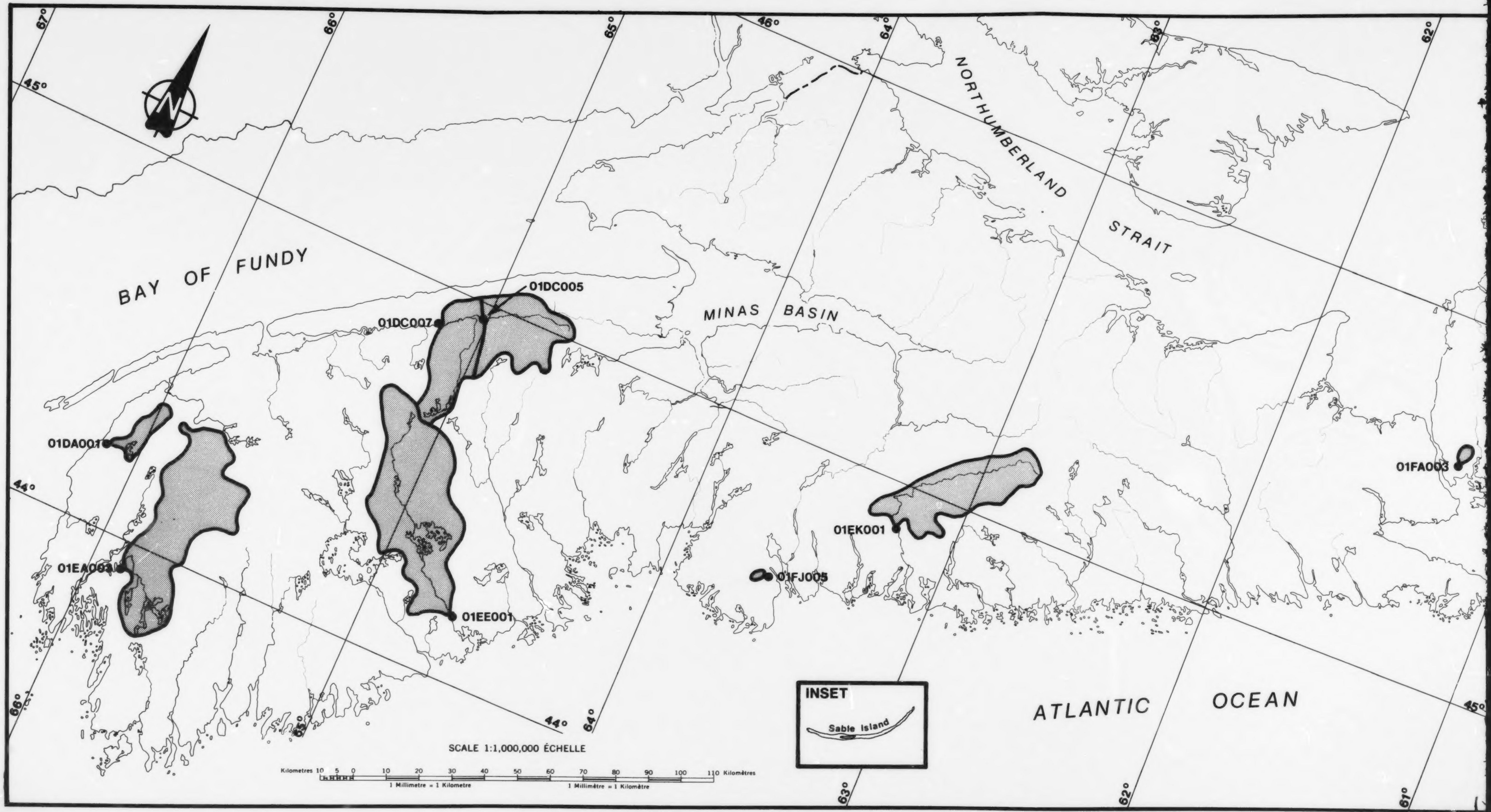
ACTIVE [1983] HYDROMETRIC STATIONS ON NATURAL FLOW WATERSHEDS

LEGEND

●01ED005	WSC STATION NUMBER AND LOCATION
▨	DRAINAGE AREA DELINEATION TO GAUGE

NOTE: STATION 01ED006 KEJIMKUJIK LAKE MEASURES WATER LEVEL ONLY.

APPENDIX E-4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NORTHUMBERLAND STRAIT
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ATLANTIC OCEAN
01DC005
01DC007
01DA001
01EA003
01EE001
01FJ005
01EK001
01FA003
INSET
Sable Island
SCALE 1:1,000,000 ÉCHELLE
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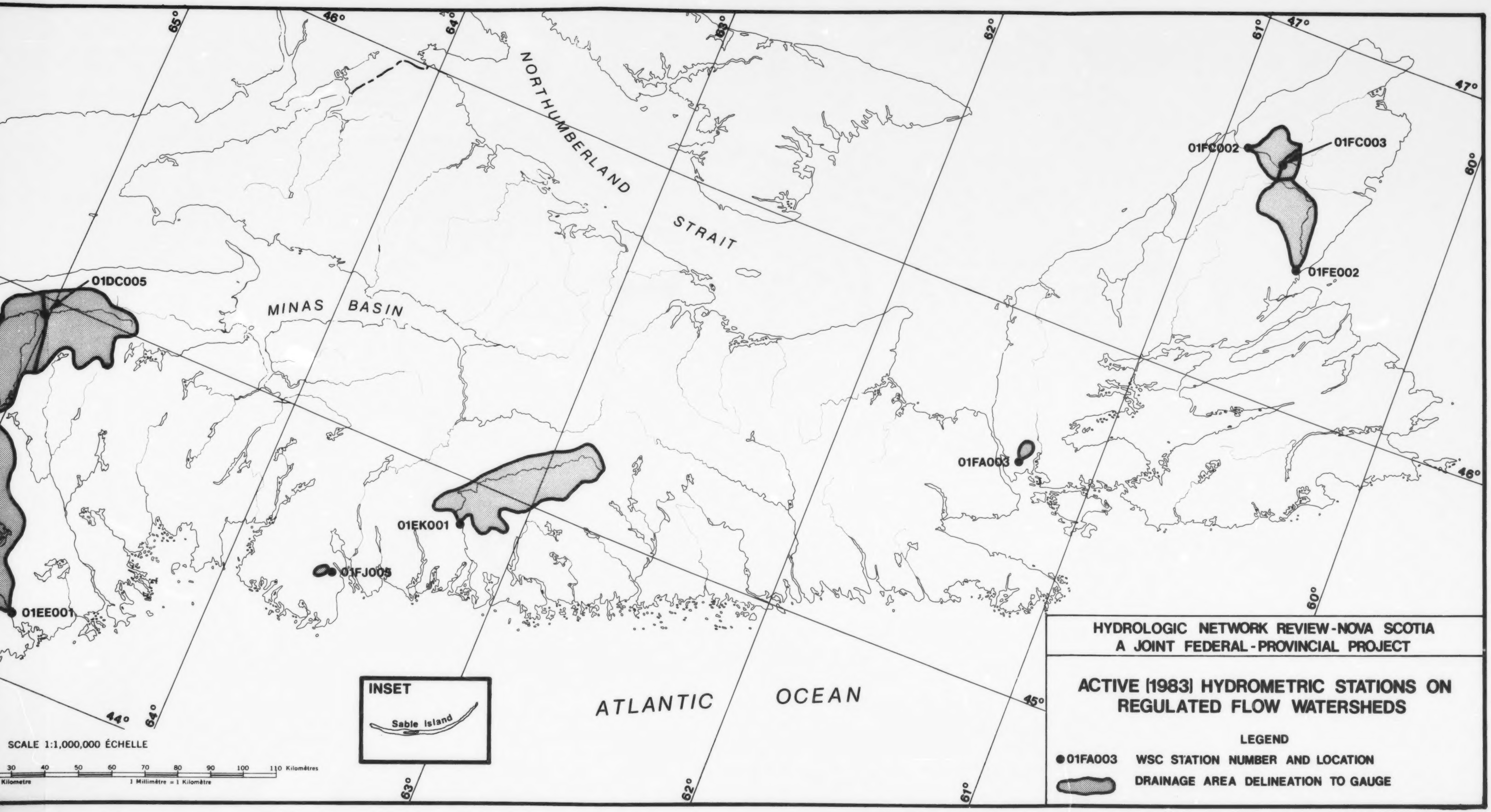
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NORTHUMBERLAND STRAIT
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SCALE 1:1,000,000 ÉCHELLE
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Kilometre
1 Millimètre = 1 Kilomètre

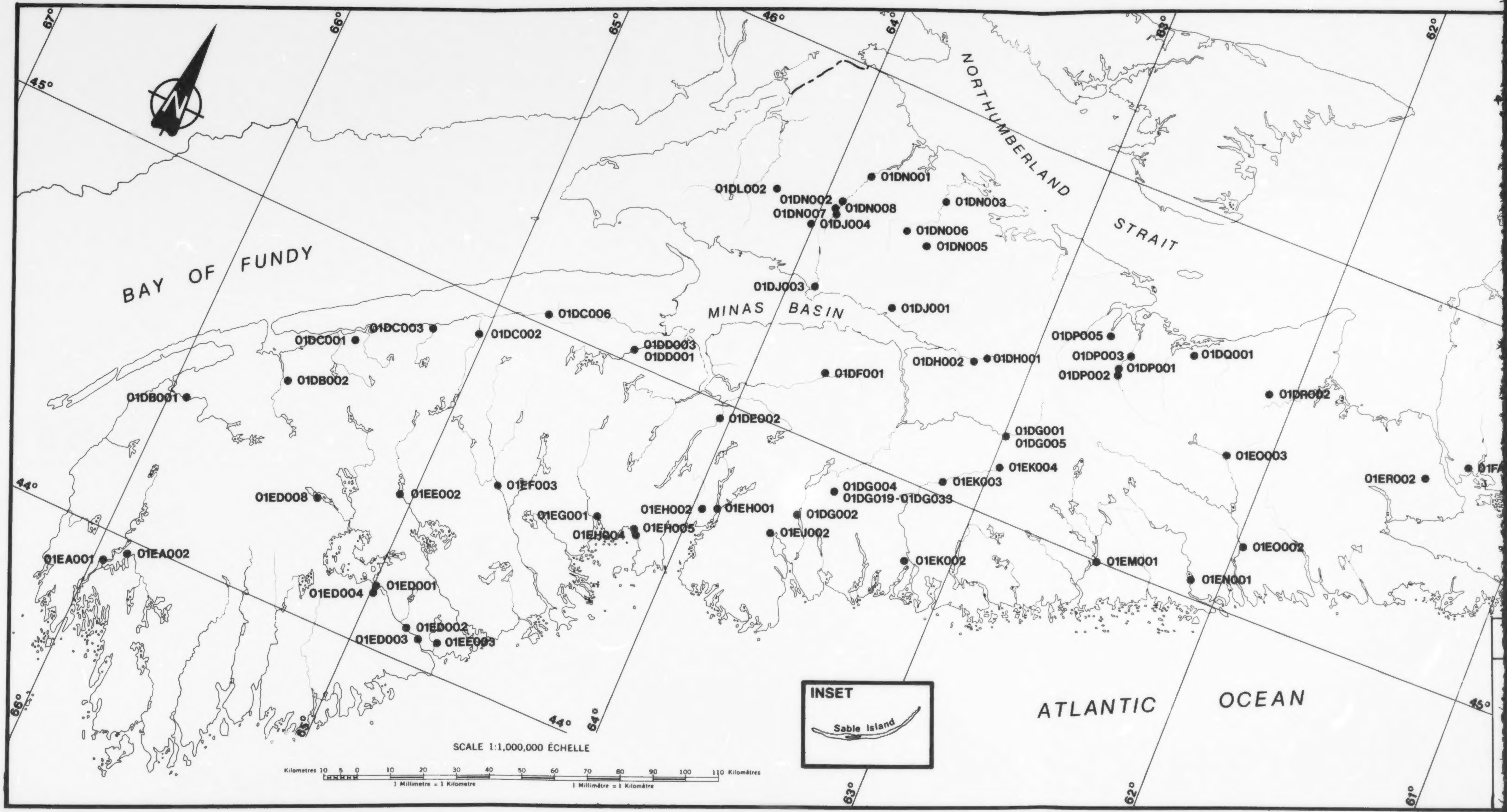
HYDROLOGIC NETWORK REVIEW-NOVA SCOTIA
A JOINT FEDERAL-PROVINCIAL PROJECT

ACTIVE [1983] HYDROMETRIC STATIONS ON REGULATED FLOW WATERSHEDS

LEGEND

● 01FA003 WSC STATION NUMBER AND LOCATION

▨ DRAINAGE AREA DELINEATION TO GAUGE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ATLANTIC OCEAN
INSET
Sable Island
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01DN008
01DN003
01DN007
01DJ004
01DN006
01DN005
01DJ003
01DJ001
01DC006
01DC003
01DC001
01DC002
01DD003
01DD001
01DF001
01DH002
01DH001
01DP005
01DP003
01DP001
01DP002
01DQ001
01DR002
01DB002
01DB001
01DE002
01DG001
01DG005
01EO003
01EK004
01EK003
01FA
01ER002
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01EE002
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01DG002
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01EH005
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01EA002
01EK002
01EM001
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01ED001
01ED004
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SCALE 1:1,000,000 ÉCHELLE
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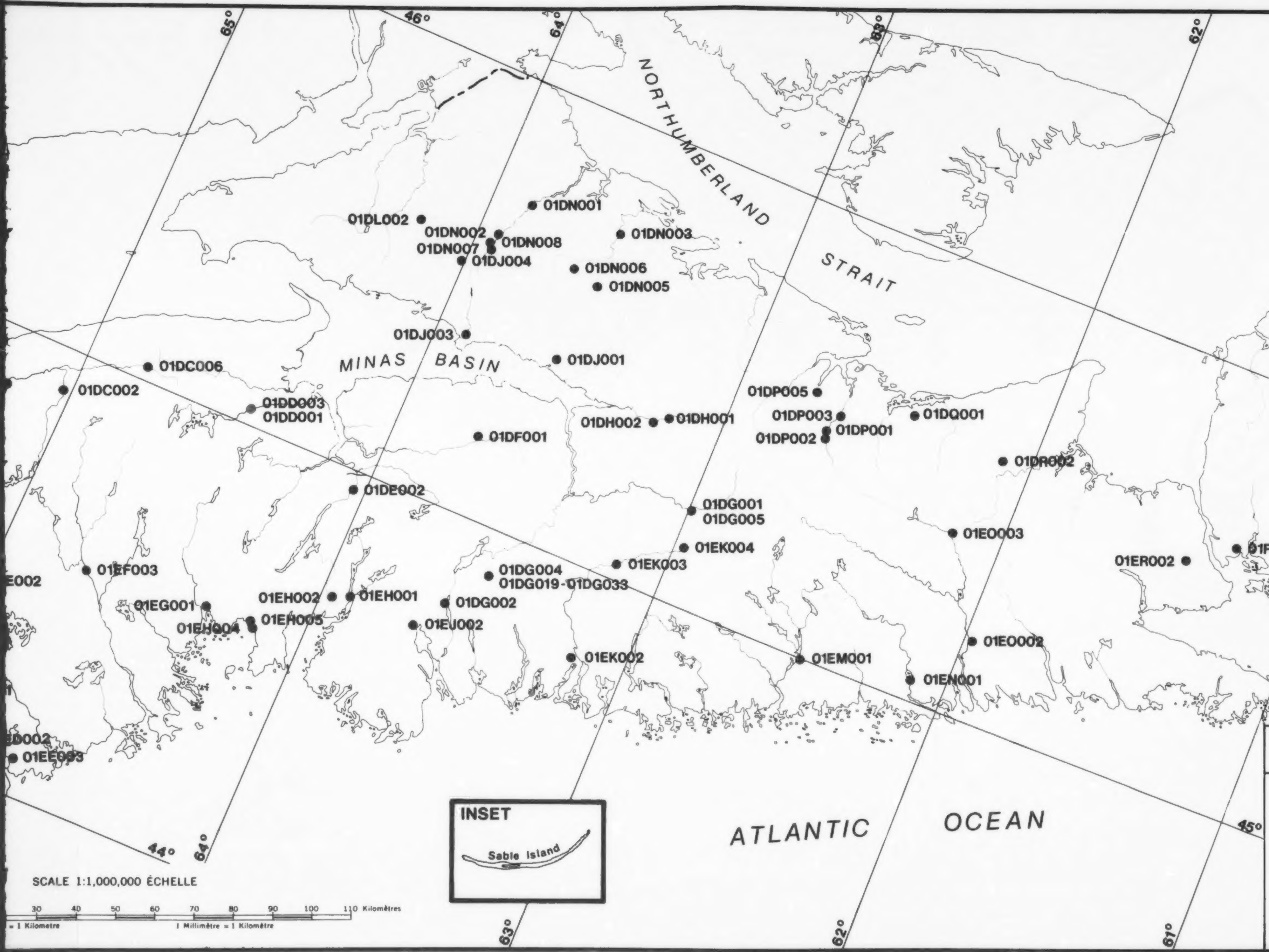
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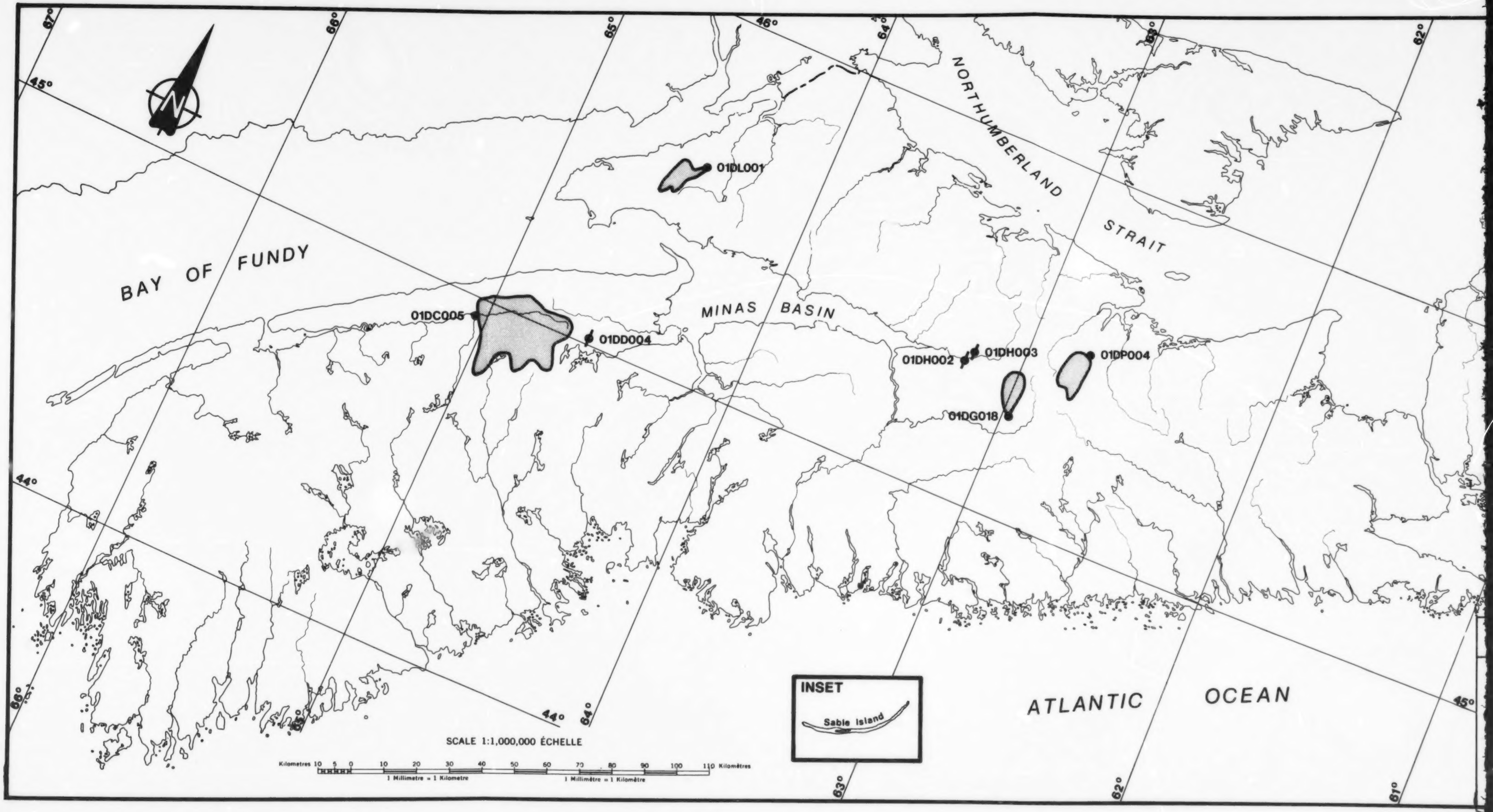
60°
NORTHUMBERLAND STRAIT
MINAS BASIN
01DL002
01DN001
01DN002
01DN008
01DN007
01DJ004
01DN003
01DN006
01DN005
01DJ003
01DJ001
01DC006
01DC002
01DD003
01DD001
01DF001
01DH002
01DH001
01DP005
01DP003
01DP001
01DP002
01DQ001
01DR002
01FC001
01FE001
01FD001
01FB002
01FB005
01FB004
01DE002
01DG001
01DG005
01EK004
01EO003
01EK003
01DG004
01DG019-01DG033
01ER002
01FA002
46°
EO02
01EF003
01EG001
01EH002
01EH001
01DG002
01EH004
01EH005
01EJ002
01EK002
01EM001
01EN001
01EO002
60°
ED002
01EE003
44°
64°
45°
INSET
Sable Island
ATLANTIC OCEAN
SCALE 1:1,000,000 ÉCHELLE
30 40 50 60 70 80 90 100 110 Kilomètres
= 1 Kilometre
1 Millimètre = 1 Kilomètre
63°
62°
61°

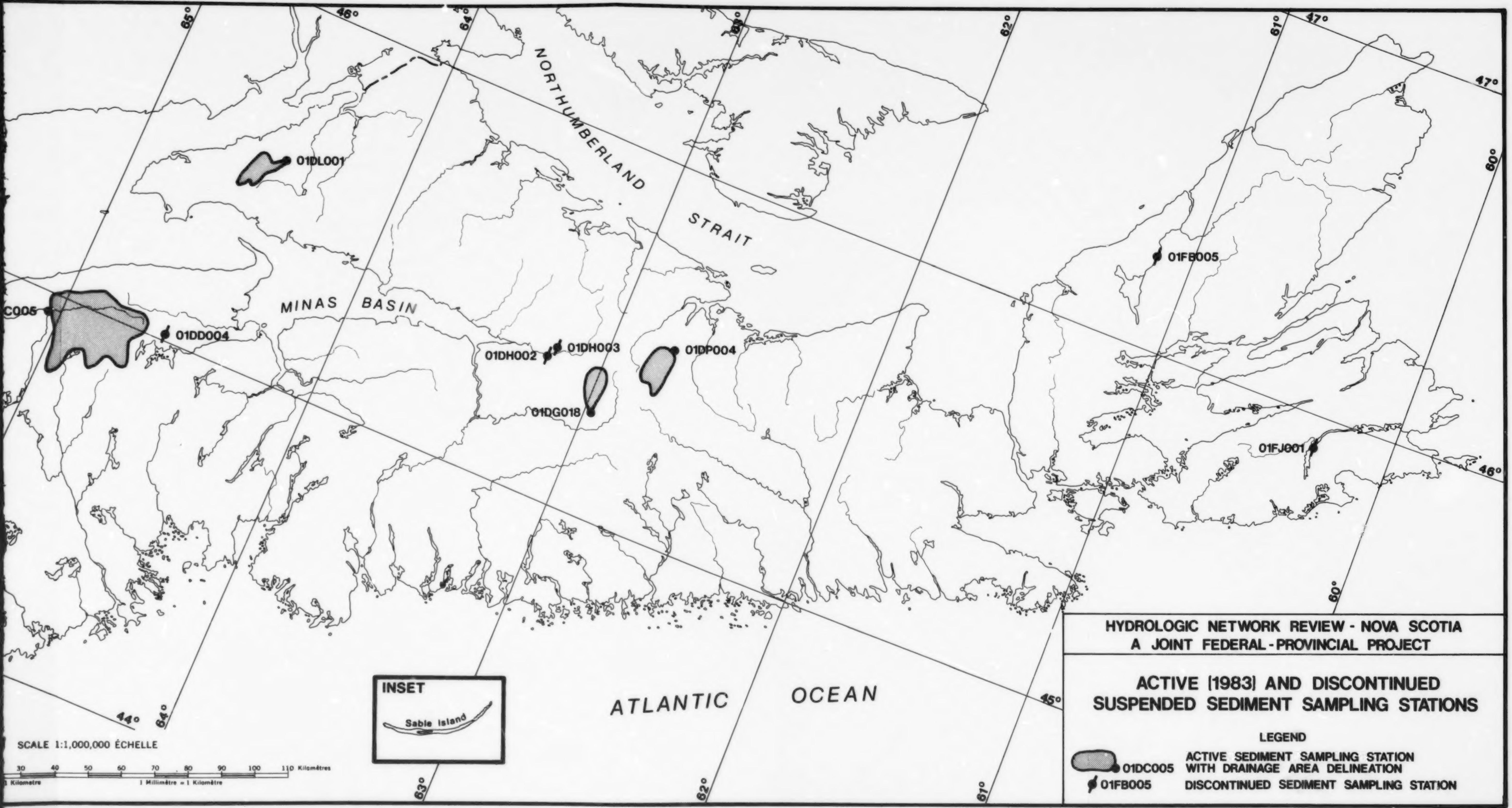
HYRDOLOGIC NETWORK REVIEW - NOVA SCOTIA
A JOINT FEDERAL - PROVINCIAL PROJECT

DISCONTINUED HYDROMETRIC STATIONS

LEGEND

● 01FE001 WSC STATION NUMBER AND LOCATION


67°
66°
65°
46°
64°
63°
62°
45°
N
NORTHUMBERLAND STRAIT
01DL001
BAY OF FUNDY
MINAS BASIN
01DC005
01DD004
01DH002
01DH003
01DP004
01DG018
44°
66°
65°
44°
64°
ATLANTIC OCEAN
45°
INSET
Sable Island
SCALE 1:1,000,000 ÉCHELLE
Kilometres 10 5 0 10 20 30 40 50 60 70 80 90 100 110 Kilomètres
1 Millimetre = 1 Kilometre
1 Millimètre = 1 Kilomètre
63°
62°
61°

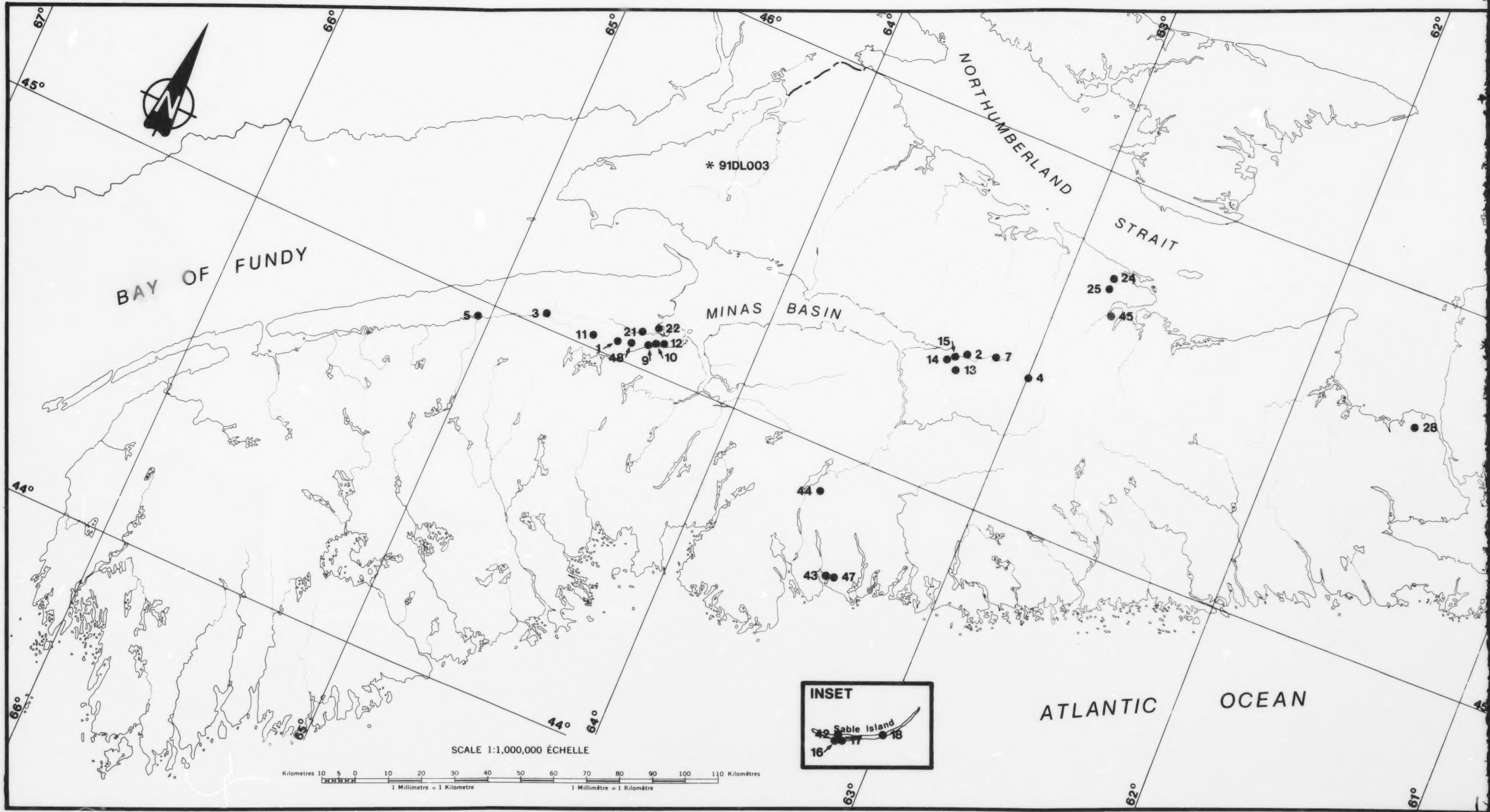

NORTHUMBERLAND STRAIT
MINAS BASIN
ATLANTIC OCEAN
01DL001
C005
01DD004
01DH002
01DH003
01DP004
01DG018
01FB005
01FJ001
INSET
Sable Island
SCALE 1:1,000,000 ÉCHELLE
30 40 50 60 70 80 90 100 110 Kilomètres
1 Kilometre
1 Millimètre = 1 Kilomètre
46°
47°
45°
44°
65°
64°
63°
62°
61°
60°

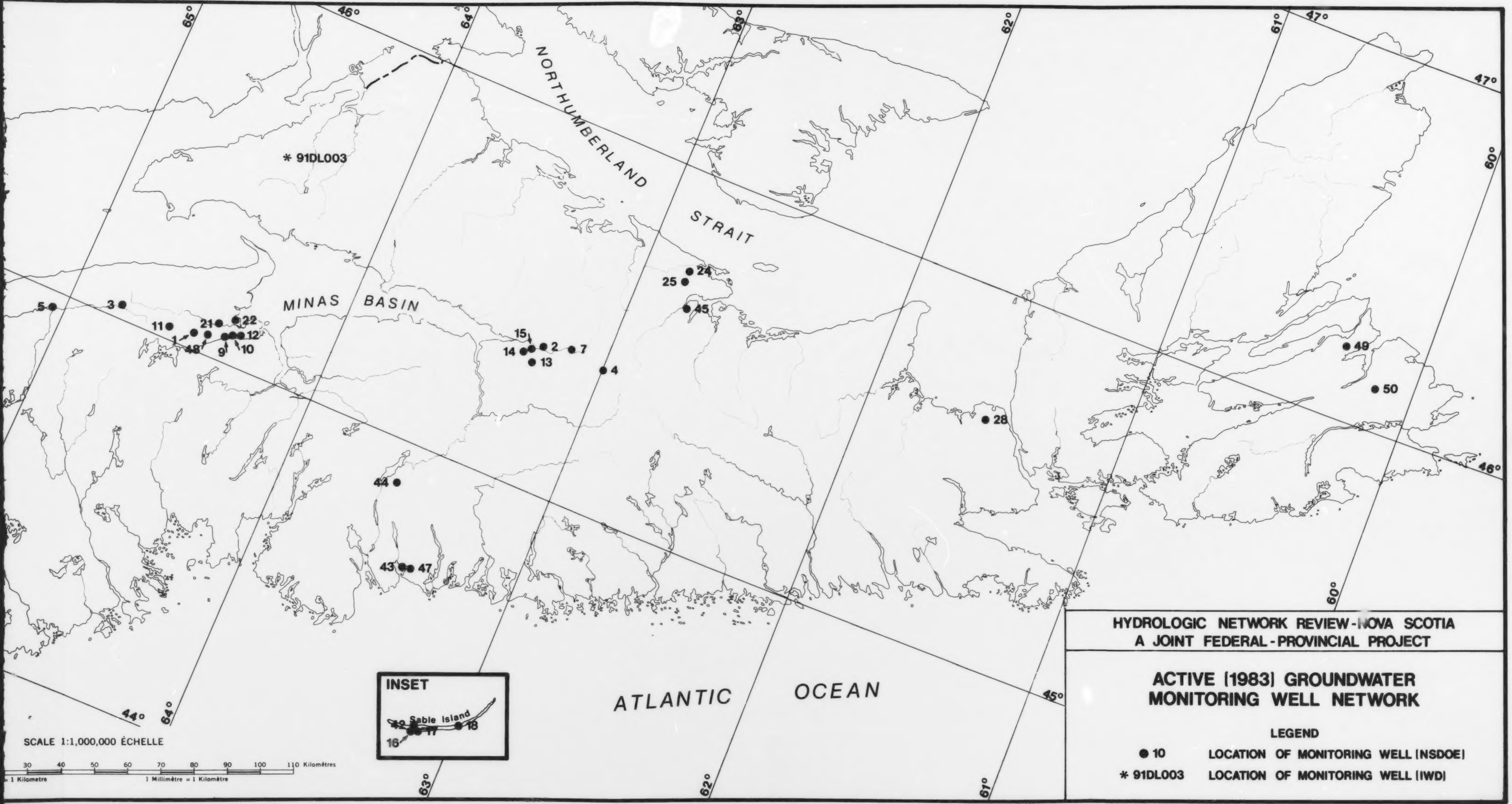
HYDROLOGIC NETWORK REVIEW - NOVA SCOTIA
A JOINT FEDERAL-PROVINCIAL PROJECT

ACTIVE [1983] AND DISCONTINUED SUSPENDED SEDIMENT SAMPLING STATIONS

LEGEND

▨ 01DC005	ACTIVE SEDIMENT SAMPLING STATION WITH DRAINAGE AREA DELINEATION
● 01FB005	DISCONTINUED SEDIMENT SAMPLING STATION


67°
66°
65°
64°
46°
63°
62°
45°
44°
44°
66°
65°
64°
63°
62°
61°
N
BAY OF FUNDY
MINAS BASIN
NORTHUMBERLAND STRAIT
ATLANTIC OCEAN
* 91DL003
5
3
11
21
22
1
48
9
10
12
15
14
2
7
13
4
24
25
45
28
44
43
47
INSET
Sable Island
42
16
17
18
SCALE 1:1,000,000 ÉCHELLE
Kilometres 10 5 0 10 20 30 40 50 60 70 80 90 100 110 Kilomètres
1 Millimetre = 1 Kilometre
1 Millimètre = 1 Kilomètre


65°
46°
64°
63°
62°
61°
47°
47°
60°
NORTHUMBERLAND
STRAIT
* 91DL003
MINAS BASIN
5
3
11
21
22
1
48
9
12
10
15
14
2
7
13
4
24
25
45
49
50
28
44
43
47
46°
60°
45°
44°
64°
63°
62°
61°
ATLANTIC OCEAN
INSET
Sable Island
42
16
17
18
SCALE 1:1,000,000 ÉCHELLE
30
40
50
60
70
80
90
100
110 Kilomètres
= 1 Kilometre
1 Millimètre = 1 Kilomètre

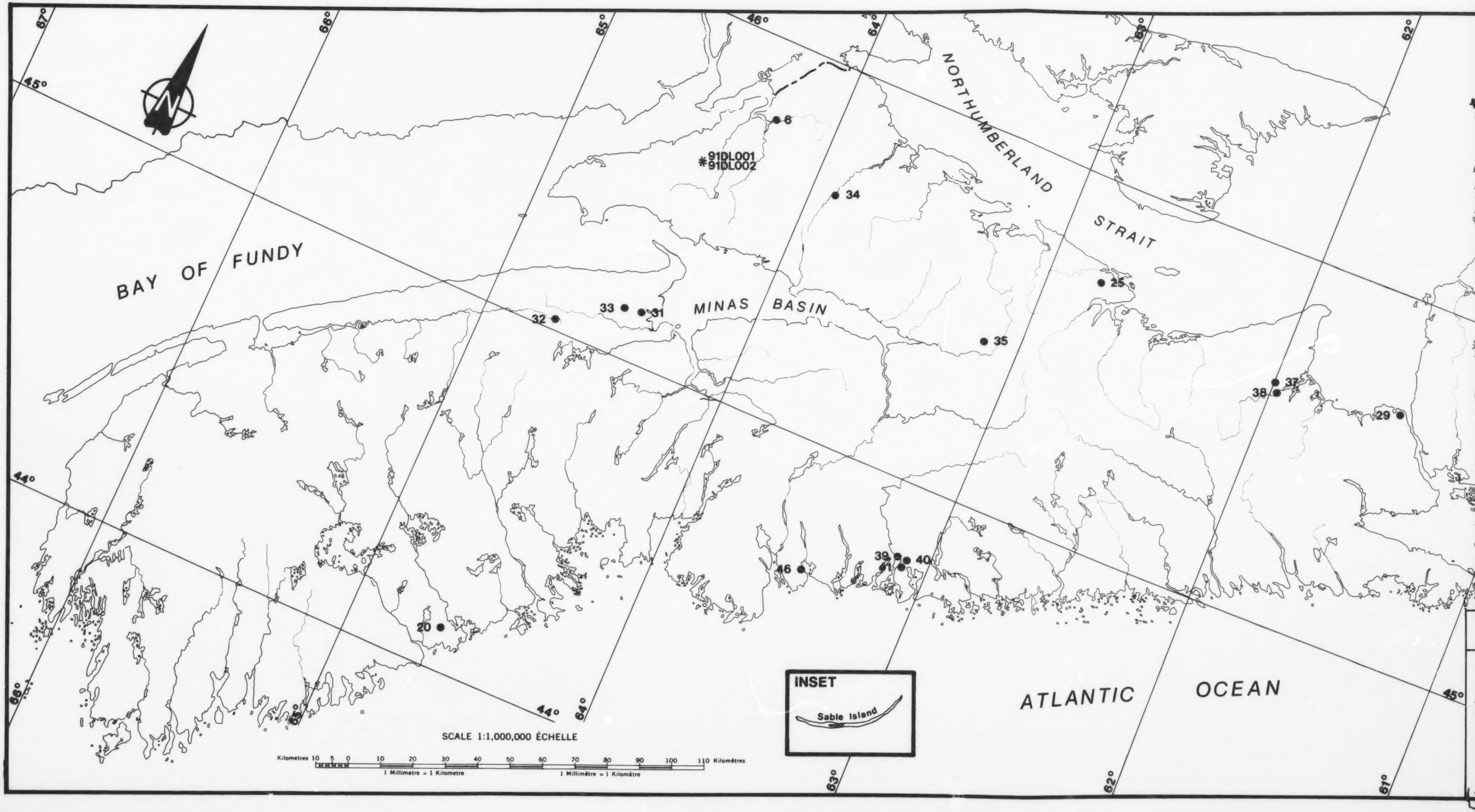
HYDROLOGIC NETWORK REVIEW-NOVA SCOTIA
A JOINT FEDERAL-PROVINCIAL PROJECT

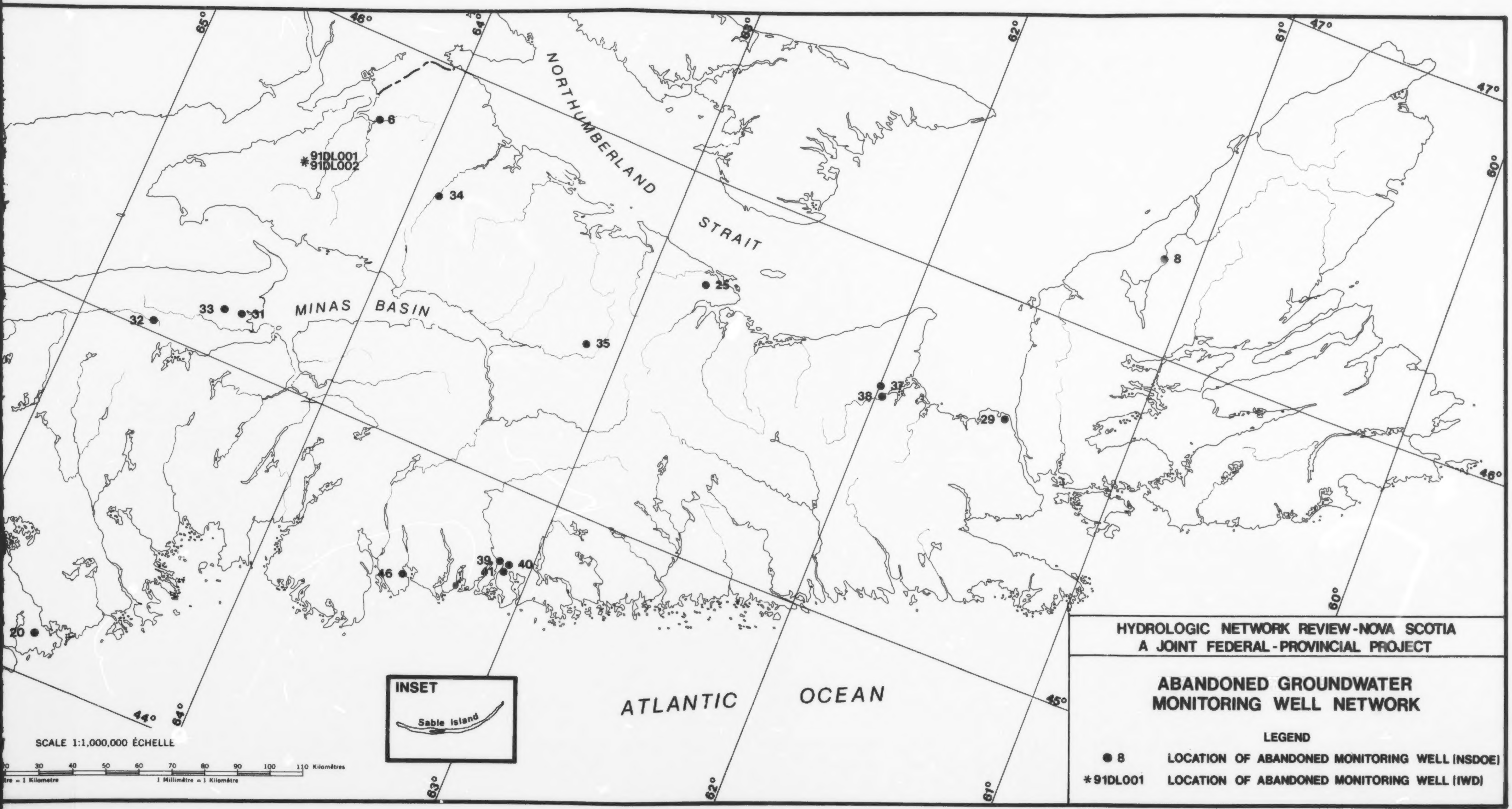
ACTIVE (1983) GROUNDWATER MONITORING WELL NETWORK

LEGEND

● 10	LOCATION OF MONITORING WELL (NSDOE)
* 91DL003	LOCATION OF MONITORING WELL (IWD)

APPENDIX E-8


BAY OF FUNDY
MINAS BASIN
NORTHUMBERLAND STRAIT
ATLANTIC OCEAN
N
67°
66°
65°
64°
63°
62°
61°
45°
44°
46°
6
91DL001
91DL002
34
25
33
31
32
35
37
38
29
39
40
41
46
20
INSET
Sable Island
SCALE 1:1,000,000 ÉCHELLE
Kilometres 10 5 0 10 20 30 40 50 60 70 80 90 100 110 Kilomètres
1 Millimetre = 1 Kilometre
1 Millimètre = 1 Kilomètre


46°
65°
64°
63°
62°
61°
47°
47°
60°
NORTHUMBERLAND STRAIT
6
*91DL001
*91DL002
34
8
25
33
31
32
MINAS BASIN
35
37
38
29
46°
39
40
41
46
20
60°
45°
44°
64°
ATLANTIC OCEAN
INSET
Sable Island
63°
62°
61°
SCALE 1:1,000,000 ÉCHELLE
20
30
40
50
60
70
80
90
100
110 Kilomètres
tre = 1 Kilometre
1 Millimètre = 1 Kilomètre

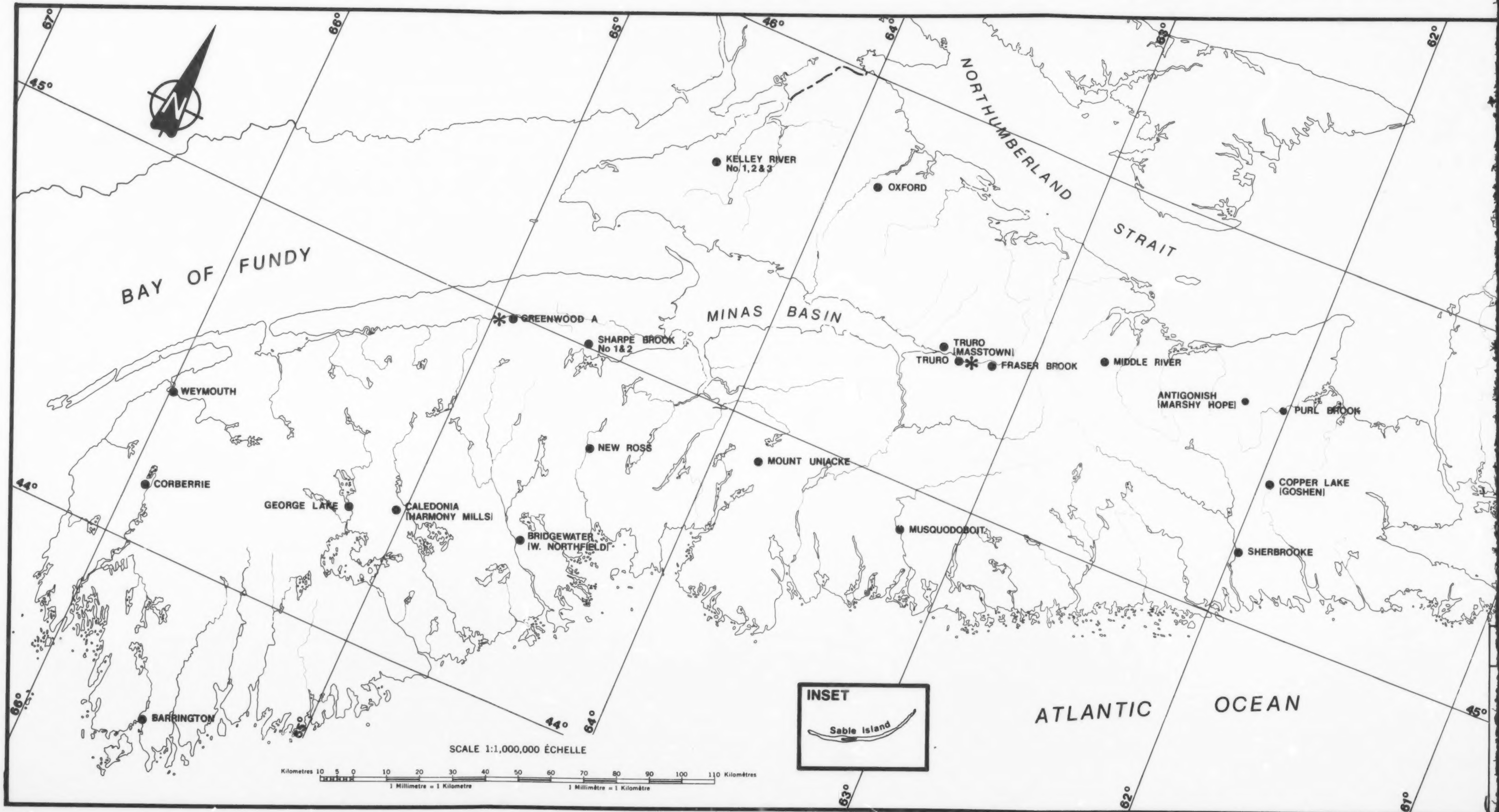
HYDROLOGIC NETWORK REVIEW-NOVA SCOTIA
A JOINT FEDERAL-PROVINCIAL PROJECT

ABANDONED GROUNDWATER MONITORING WELL NETWORK

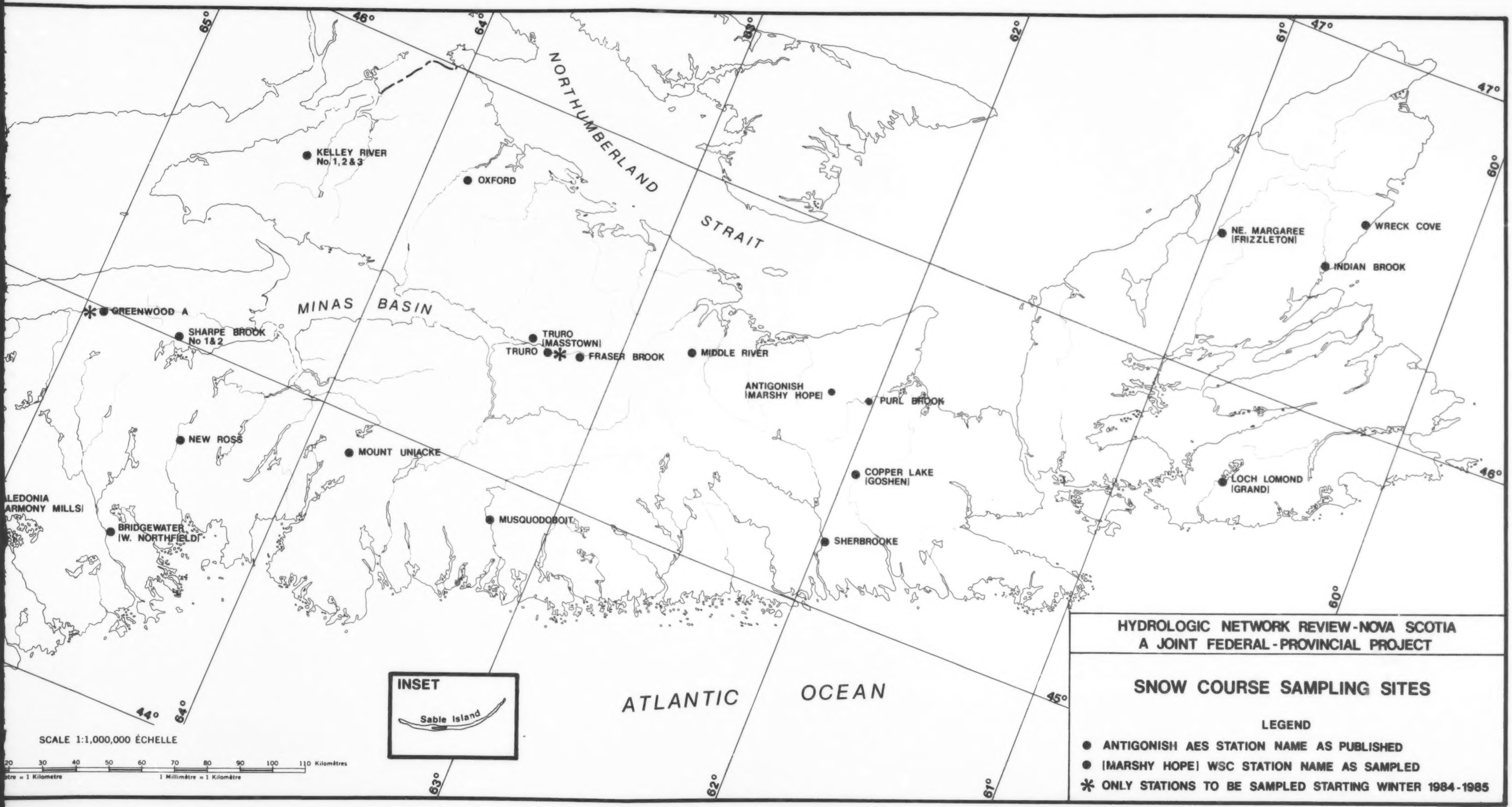
LEGEND

● 8	LOCATION OF ABANDONED MONITORING WELL (NSDOE)
*91DL001	LOCATION OF ABANDONED MONITORING WELL (IWD)

APPENDIX E-9



67°
66°
65°
46°
64°
63°
62°
45°
N
NORTHUMBERLAND
STRAIT
KELLEY RIVER No. 1, 2 & 3
OXFORD
BAY OF FUNDY
MINAS BASIN
GREENWOOD A
SHARPE BROOK No 1 & 2
TRURO (MASSTOWN)
TRURO
FRASER BROOK
MIDDLE RIVER
WEYMOUTH
ANTIGONISH (MARSHY HOPE)
PURL BROOK
NEW ROSS
MOUNT UNIACKE
44°
CORBERRIE
COPPER LAKE (GOSHEN)
GEORGE LAKE
CALEDONIA (HARMONY MILLS)
BRIDGEWATER (W. NORTHFIELD)
MUSQUODOBOIT
SHERBROOKE
66°
INSET
Sable Island
ATLANTIC
OCEAN
45°
BARRINGTON
65°
44°
64°
SCALE 1:1,000,000 ÉCHELLE
Kilometres 10 5 0 10 20 30 40 50 60 70 80 90 100 110 Kilomètres
1 Millimetre = 1 Kilometre
1 Millimètre = 1 Kilomètre
63°
62°
61°



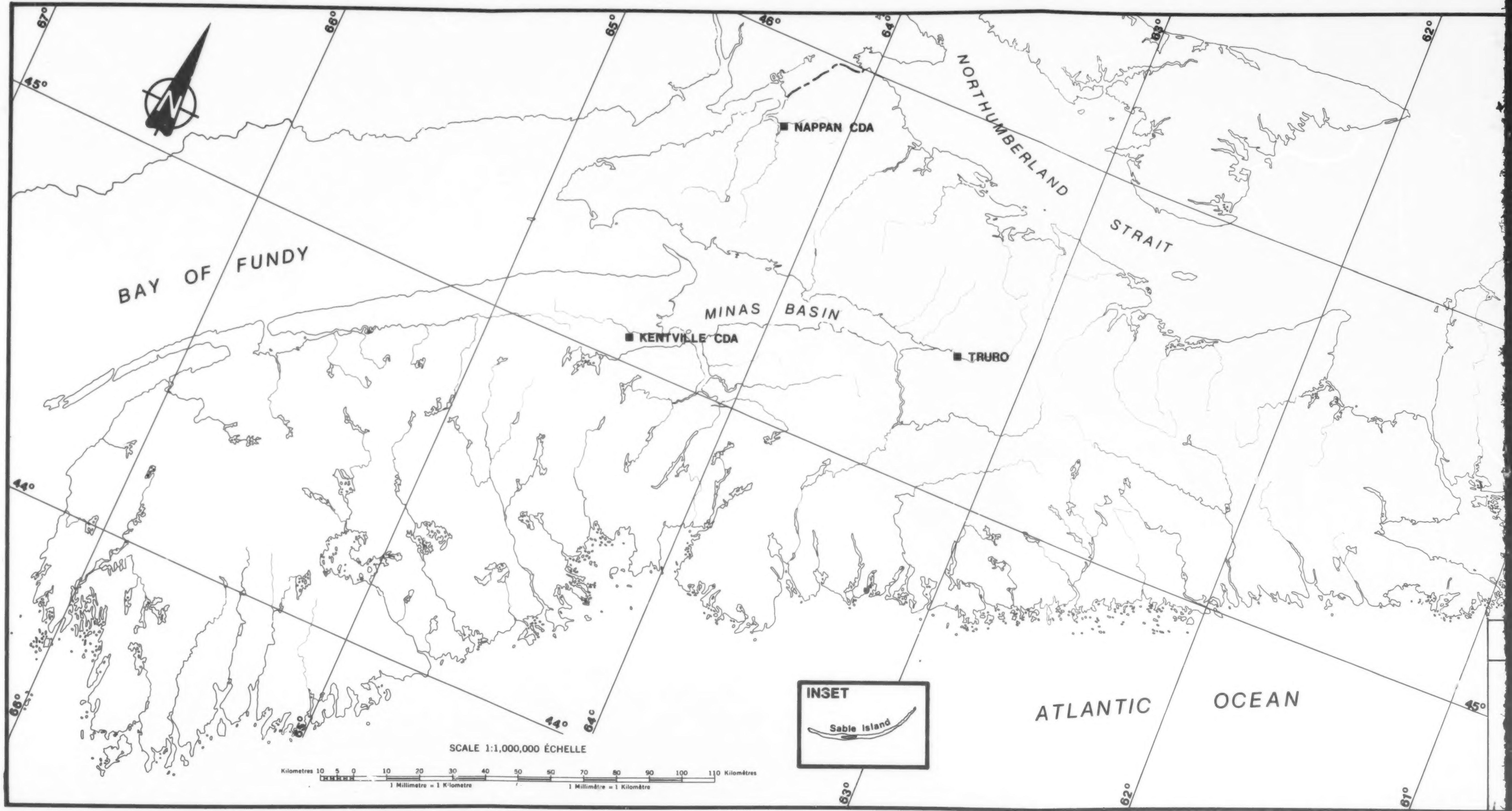
NORTHUMBERLAND STRAIT
MINAS BASIN
ATLANTIC OCEAN
KELLEY RIVER No 1,2&3
OXFORD
GREENWOOD A
SHARPE BROOK No 1&2
TRURO (MASSTOWN)
TRURO
FRASER BROOK
MIDDLE RIVER
ANTIGONISH (MARSHY HOPE)
PURL BROOK
NEW ROSS
MOUNT UNIACKE
COPPER LAKE (GOSHEN)
ALEDONIA
ARMONY MILLS)
BRIDGEWATER (W. NORTHFIELD)
MUSQUODOBOIT
SHERBROOKE
NE. MARGAREE (FRIZZLETON)
WRECK COVE
INDIAN BROOK
LOCH LOMOND (GRAND)
INSET
Sable Island
46°
47°
47°
46°
45°
44°
65°
64°
63°
62°
61°
60°
60°
64°
63°
62°
61°
60°
SCALE 1:1,000,000 ÉCHELLE
20 30 40 50 60 70 80 90 100 110 Kilomètres
tre = 1 Kilometre
1 Millimètre = 1 Kilomètre

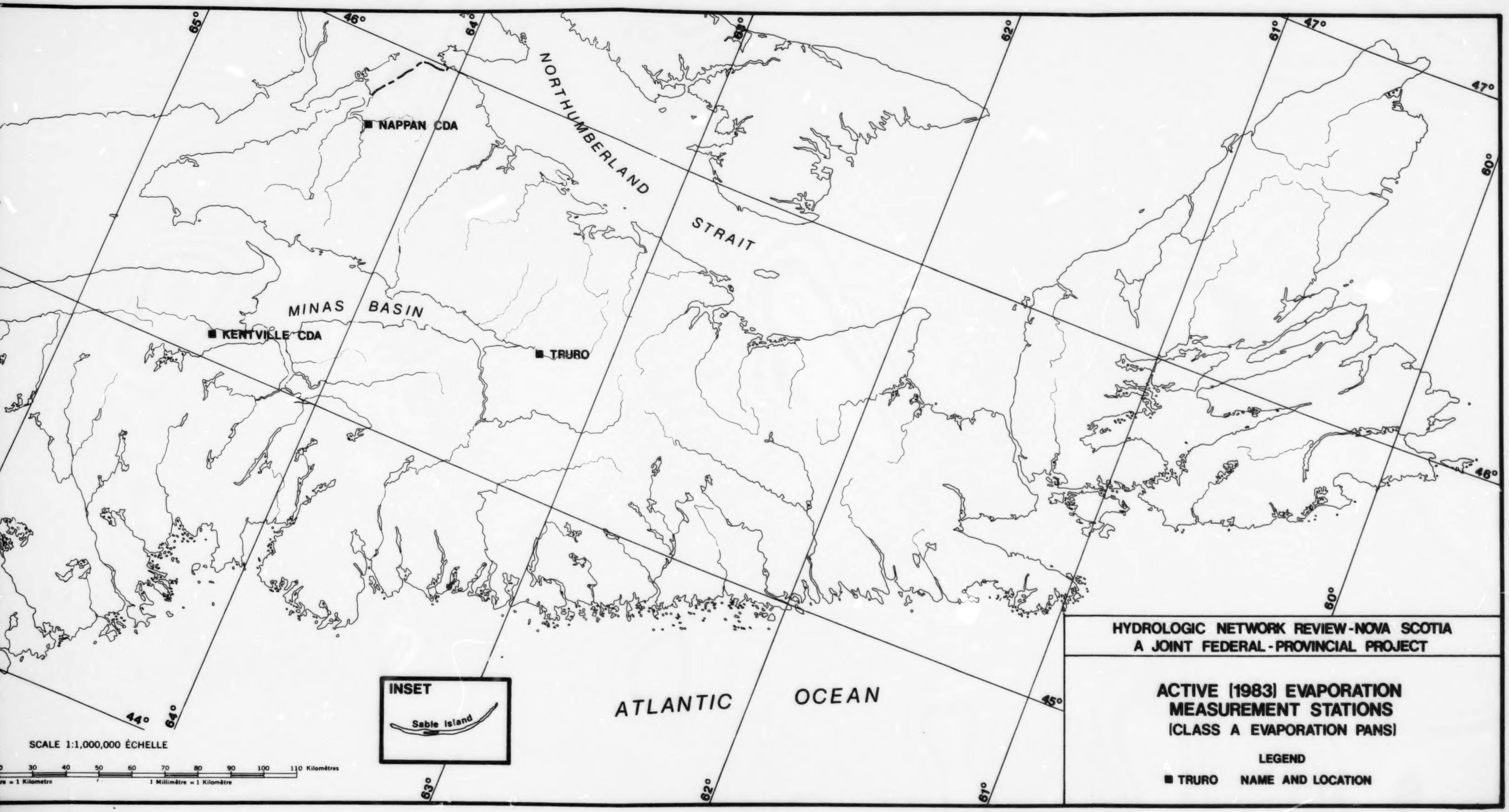
HYDROLOGIC NETWORK REVIEW-NOVA SCOTIA
A JOINT FEDERAL-PROVINCIAL PROJECT

SNOW COURSE SAMPLING SITES

LEGEND

- ● ANTIGONISH AES STATION NAME AS PUBLISHED
- ● (MARSHY HOPE) WSC STATION NAME AS SAMPLED
- * ONLY STATIONS TO BE SAMPLED STARTING WINTER 1984-1985


N
BAY OF FUNDY
MINAS BASIN
NORTHUMBERLAND STRAIT
ATLANTIC OCEAN
NAPPAN CDA
KENTVILLE CDA
TRURO
INSET
Sable Island
67°
66°
65°
64°
63°
62°
61°
46°
45°
44°
SCALE 1:1,000,000 ÉCHELLE
Kilometres 10 5 0 10 20 30 40 50 60 70 80 90 100 110 Kilomètres
1 Millimetre = 1 Kilometre
1 Millimètre = 1 Kilomètre


NAPPAN CDA
KENTVILLE CDA
TRURO
MINAS BASIN
NORTHUMBERLAND
STRAIT
ATLANTIC
OCEAN
INSET
Sable Island
46°
47°
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44°
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63°
62°
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60°
SCALE 1:1,000,000 ÉCHELLE
30
40
50
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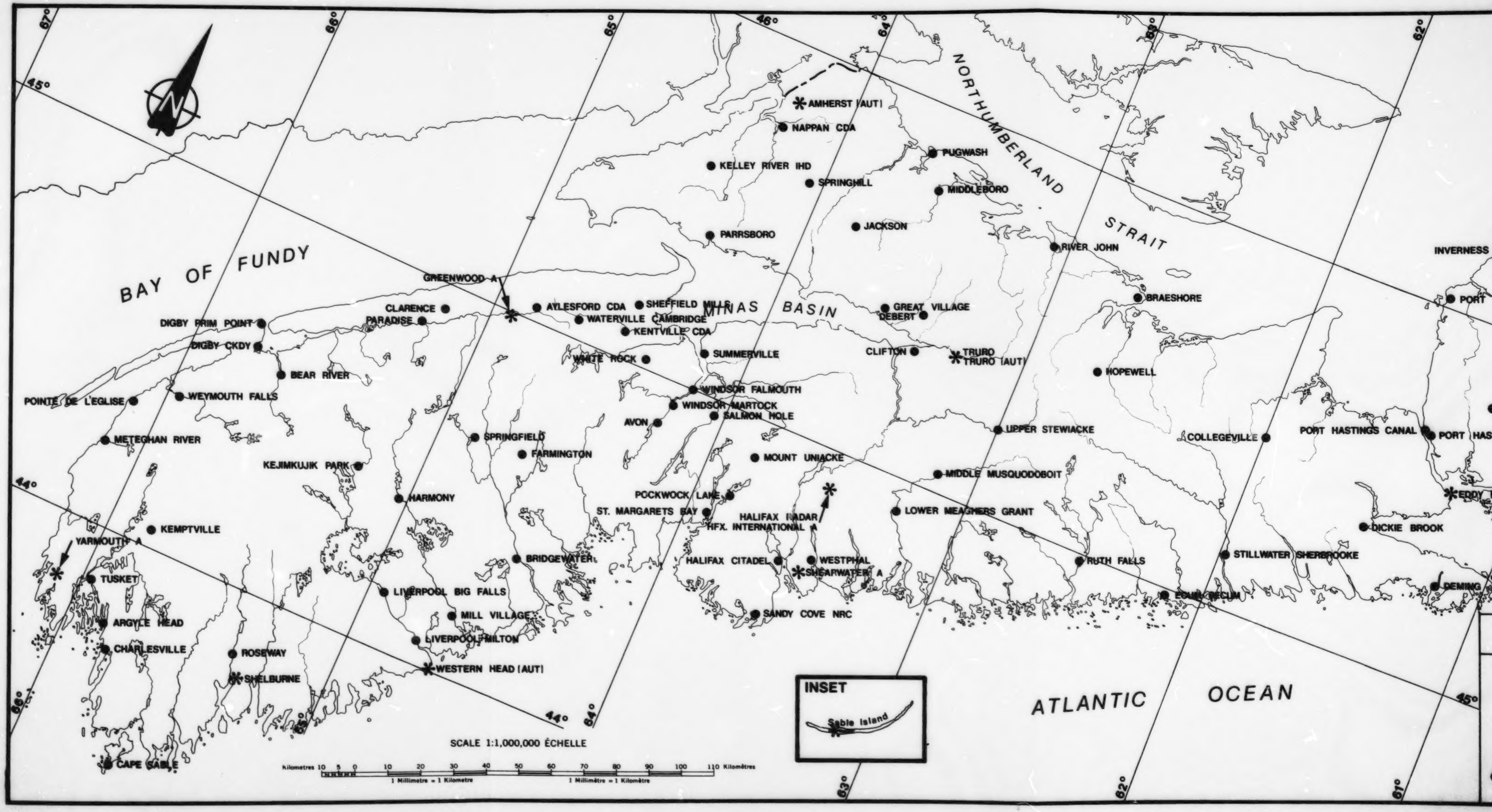
70
80
90
100
110 Kilomètres
1 Millimètre = 1 Kilomètre

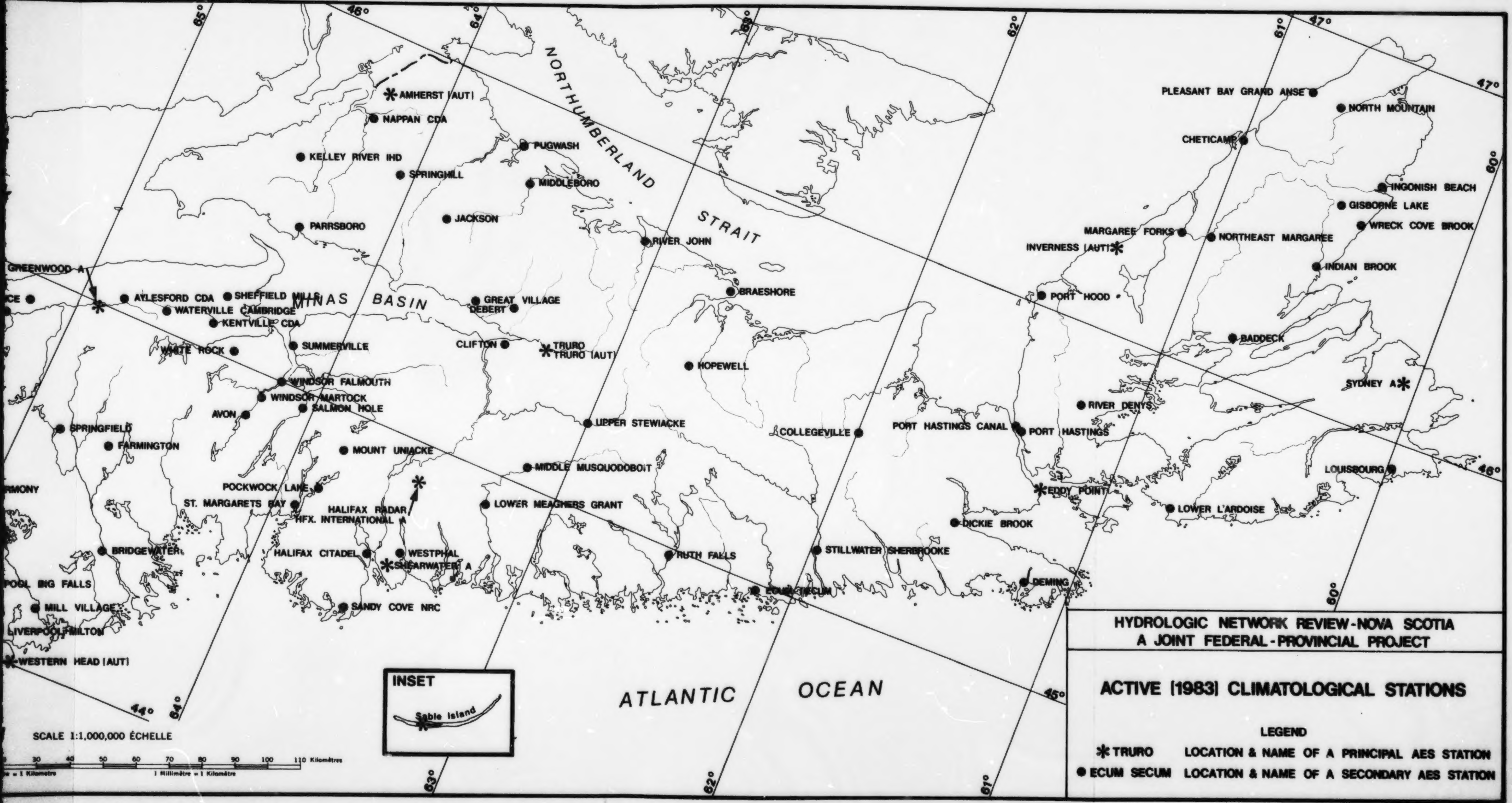
HYDROLOGIC NETWORK REVIEW-NOVA SCOTIA
A JOINT FEDERAL-PROVINCIAL PROJECT

ACTIVE [1983] EVAPORATION MEASUREMENT STATIONS
[CLASS A EVAPORATION PANS]

LEGEND

■ TRURO NAME AND LOCATION


BAY OF FUNDY
MINAS BASIN
NORTHUMBERLAND STRAIT
ATLANTIC OCEAN
AMHERST (AUT)
NAPPAN CDA
KELLEY RIVER IHD
SPRINGHILL
PUGWASH
MIDDLEBORO
JACKSON
PARRSBORO
RIVER JOHN
INVERNESS
BRAESHORE
PORT
GREENWOOD A
CLARENCE
PARADISE
AYLESFORD CDA
SHEFFIELD MILLS
WATERVILLE CAMBRIDGE
KENTVILLE CDA
GREAT VILLAGE
DEBERT
DIGBY PRIM POINT
DIGBY CKDY
SUMMERVILLE
CLIFTON
TRURO
TRURO (AUT)
WHITE ROCK
HOPEWELL
BEAR RIVER
WINDSOR FALMOUTH
WINDSOR MARTOCK
SALMON HOLE
POINTE DE L'EGLISE
WEYMOUTH FALLS
AVON
UPPER STEWIACKE
METEGHAN RIVER
SPRINGFIELD
FARMINGTON
COLLEGEVILLE
PORT HASTINGS CANAL
PORT HAS
MOUNT UNIACKE
KEJIMKUJIK PARK
MIDDLE MUSQUODOBOIT
HARMONY
POCKWOCK LAKE
EDDY
ST. MARGARETS BAY
HALIFAX RADAR
LOWER MEAGHERS GRANT
HFX. INTERNATIONAL A
KEMPTVILLE
DICKIE BROOK
YARMOUTH A
BRIDGEWATER
STILLWATER SHERBROOKE
HALIFAX CITADEL
WESTPHAL
RUTH FALLS
TUSKET
SHEARWATER A
DEMING
LIVERPOOL BIG FALLS
ECUM SECUM
MILL VILLAGE
SANDY COVE NRC
ARGYLE HEAD
LIVERPOOL MILTON
CHARLESVILLE
ROSEWAY
WESTERN HEAD (AUT)
SHELBURNE
INSET
Sable Island
CAPE SABLE
SCALE 1:1,000,000 ÉCHELLE
Kilomètres 10 5 0 10 20 30 40 50 60 70 80 90 100 110 Kilomètres
1 Millimetre = 1 Kilometre
1 Millimètre = 1 Kilomètre
67°
66°
65°
64°
63°
62°
61°
45°
46°
44°
N



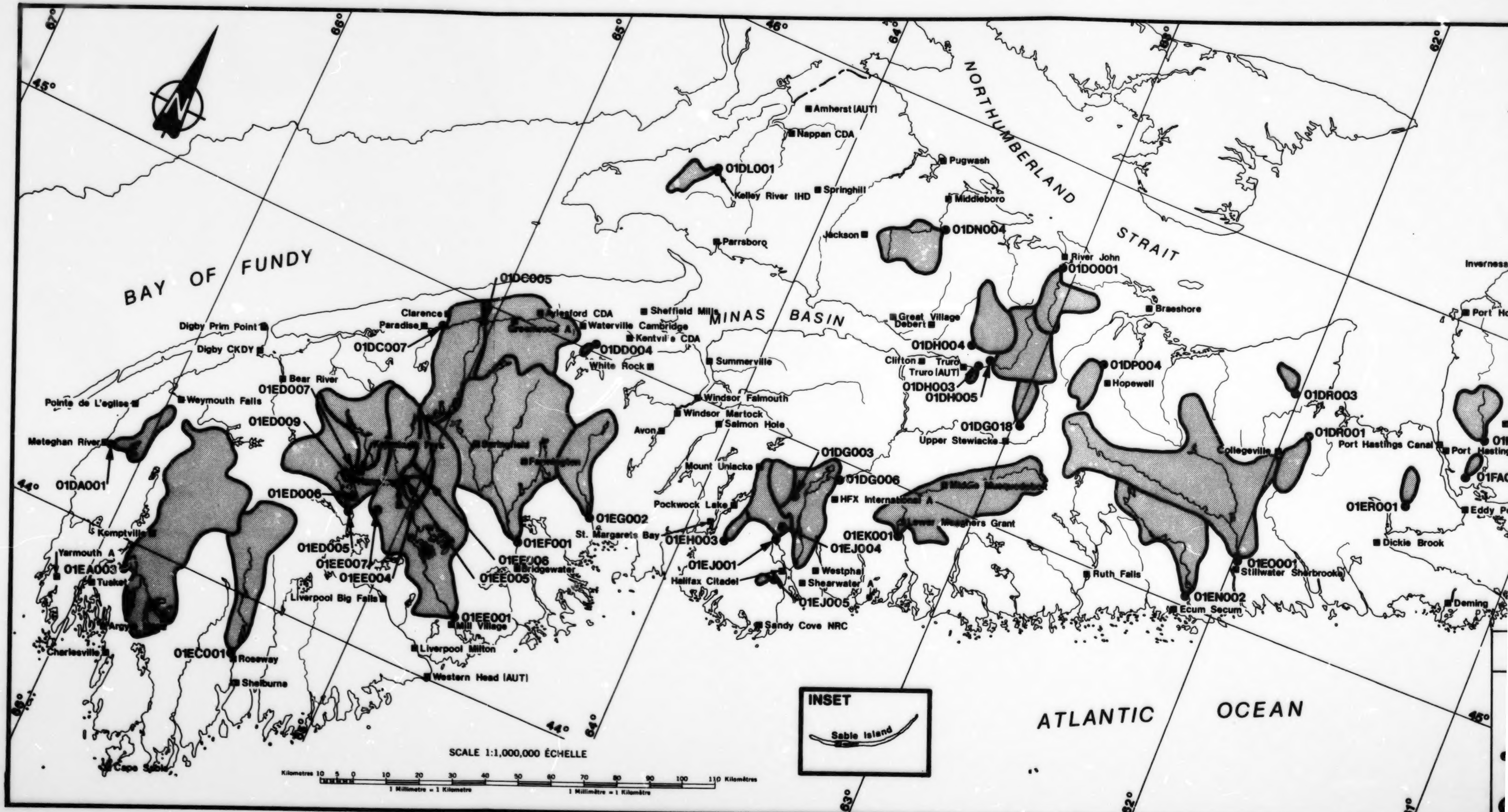
NORTHUMBERLAND STRAIT
MINAS BASIN
ATLANTIC OCEAN
46°
47°
45°
44°
65°
64°
63°
62°
61°
60°
AMHERST (AUT)
NAPPAN CDA
PUGWASH
KELLEY RIVER IHD
SPRINGHILL
MIDDLEBORO
JACKSON
PARRSBORO
RIVER JOHN
GREENWOOD A
CE
AYLESFORD CDA
SHEFFIELD MILLS
WATERVILLE CAMBRIDGE
KENTVILLE CDA
GREAT VILLAGE
DEBERT
BRAESHORE
SUMMERVILLE
CLIFTON
TRURO
TRURO (AUT)
WHITE ROCK
HOPEWELL
WINDSOR FALMOUTH
WINDSOR MARTOCK
SALMON HOLE
AVON
UPPER STEWIACKE
SPRINGFIELD
FARMINGTON
MOUNT UNIACKE
COLLEGEVILLE
PORT HASTINGS CANAL
PORT HASTINGS
MIDDLE MUSQUODOBOIT
RMONY
POCKWOCK LAKE
ST. MARGARETS BAY
HALIFAX RADAR
HFX. INTERNATIONAL A
LOWER MEAGHERS GRANT
BRIDGEWATER
HALIFAX CITADEL
WESTPHAL
SHEARWATER A
RUTH FALLS
STILLWATER SHERBROOKE
DICKIE BROOK
POOL BIG FALLS
DEMING
ECUM SECUM
SANDY COVE NRC
MILL VILLAGE
LIVERPOOL MILTON
WESTERN HEAD (AUT)
PLEASANT BAY GRAND ANSE
NORTH MOUNTAIN
CHETICAMP
INGONISH BEACH
GISBORNE LAKE
WRECK COVE BROOK
MARGAREE FORKS
NORTHEAST MARGAREE
INVERNESS (AUT)
INDIAN BROOK
PORT HOOD
BADDECK
SYDNEY A
RIVER DENYS
LOUISBOURG
EDDY POINT
LOWER L'ARDOISE
INSET
Sable Island
SCALE 1:1,000,000 ÉCHELLE
30 40 50 60 70 80 90 100 110 Kilomètres
1 Millimètre = 1 Kilomètre

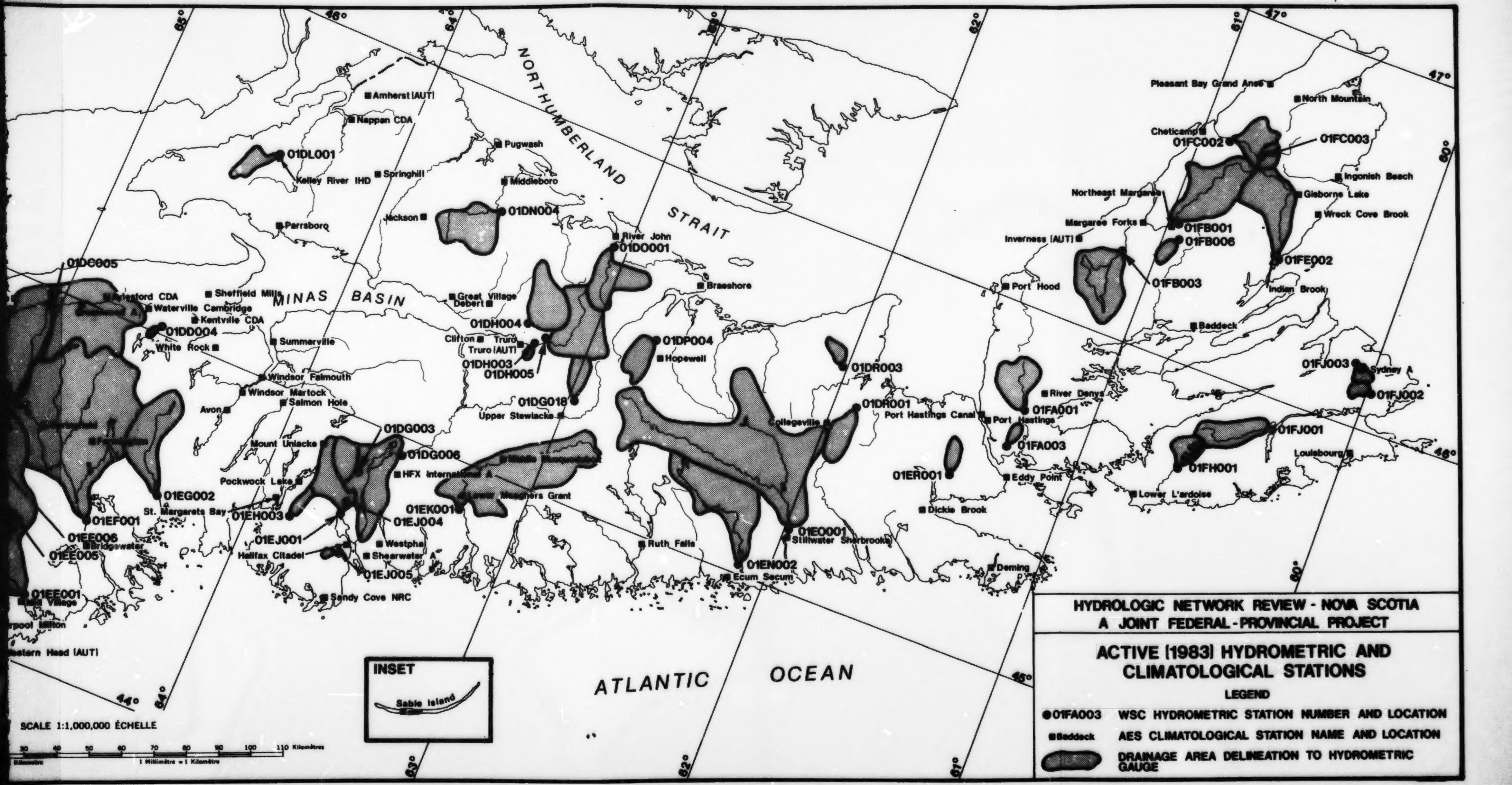
HYDROLOGIC NETWORK REVIEW-NOVA SCOTIA
A JOINT FEDERAL-PROVINCIAL PROJECT

ACTIVE (1983) CLIMATOLOGICAL STATIONS

LEGEND

✱ TRURO	LOCATION & NAME OF A PRINCIPAL AES STATION
● ECUM SECUM	LOCATION & NAME OF A SECONDARY AES STATION


N
45°
67°
66°
65°
46°
64°
63°
62°
44°
BAY OF FUNDY
MINAS BASIN
NORTHUMBERLAND STRAIT
ATLANTIC OCEAN
Amherst (AUT)
Nappan CDA
01DL001
Kelley River IHD
Springhill
Pugwash
Middleboro
01DN004
Jackson
Parrsboro
River John
01DO001
Braeshore
Inverness
Port Hood
01DC005
Clarence
Paradise
Aylesford CDA
Greenwood A
Waterville Cambridge
Sheffield Mills
Kentville CDA
Digby Prim Point
Digby CKDY
01DC007
01DD004
White Rock
Great Village
Debert
Summerville
Bear River
01ED007
Pointe de L'eglise
Weymouth Falls
01ED009
Meteghan River
01DA001
Windsor Falmouth
Windsor Martock
Salmon Hole
Avon
01DH004
Clifton
Truro
Truro (AUT)
01DH003
01DH005
01DP004
Hopewell
01DR003
01DG018
Upper Stewiacke
01DR001
Port Hastings Canal
Port Hastings
Collegeville
01DG003
01DG006
Mount Uniacke
Pockwock Lake
HFX International A
Middle Musquodoboit
Lower Meaghers Grant
01ED006
Kemptville
Yarmouth A
01EA003
Tusket
Argyle
Charlesville
01ED005
01EE007
01EE004
01EF006
Bridgewater
01EE005
01EF001
01EG002
St. Margarets Bay
01EH003
01EJ001
Halifax Citadel
Westphal
Shearwater A
01EJ005
01EJ004
01EK001
Ruth Falls
01EN002
Ecum Secum
01EO001
Stillwater Sherbrooke
01ER001
Dickie Brook
Eddy Point
Deming
Liverpool Big Falls
01EE001
Mill Village
Liverpool Milton
Western Head (AUT)
01EC001
Roseway
Shelburne
Sandy Cove NRC
Cape Sable
INSET
Sable Island
SCALE 1:1,000,000 ÉCHELLE
Kilometres 10 5 0 10 20 30 40 50 60 70 80 90 100 110 Kilomètres
1 Millimetre = 1 Kilometre
1 Millimètre = 1 Kilomètre

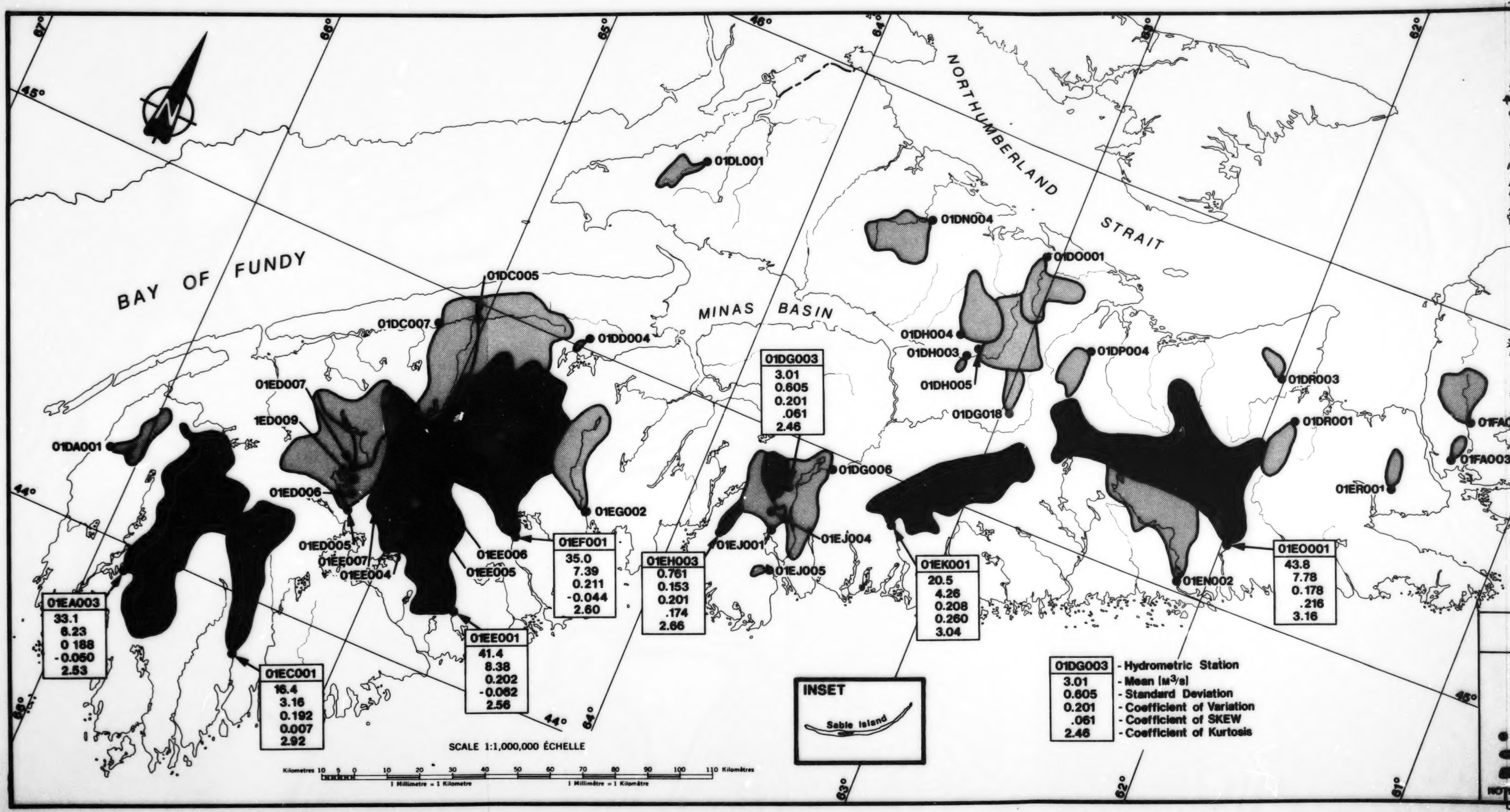

NORTHUMBERLAND STRAIT
MINAS BASIN
ATLANTIC OCEAN
46°
47°
45°
44°
65°
64°
63°
62°
61°
60°
Amherst (AUT)
Nappan CDA
Pugwash
01DL001
Kelley River IHD
Springhill
Middleboro
Jackson
01DN004
Parrsboro
River John
01DO001
01DC005
Aylesford CDA
Waterville Cambridge
Sheffield Mills
Kentville CDA
01DD004
White Rock
Summerville
Great Village
Debert
01DH004
Clifton
Truro
Truro (AUT)
01DH003
01DH005
Braeshore
01DP004
Hopewell
01DR003
Windsor Falmouth
Windsor Martock
Salmon Hole
Avon
01DG018
Upper Stewiacke
01DR001
Collegeville
Mount Uniacke
01DG003
01DG006
HFX International A
Middle Musquodoboit
Lower Meaghers Grant
Pockwock Lake
St. Margarets Bay
01EG002
01EH003
01EF001
01EE006
01EE005
Bridgewater
01EJ001
01EJ004
01EK001
Westphal
Halifax Citadel
Shearwater
01EJ005
Sandy Cove NRC
01EE001
Mill Village
Liverpool Milton
Western Head (AUT)
Ruth Falls
01EO001
Stillwater Sherbrooke
01EN002
Ecum Secum
Pleasant Bay Grand Anse
North Mountain
Cheticamp
01FC002
01FC003
Ingonish Beach
Northeast Margaree
Gisborne Lake
Wreck Cove Brook
Margaree Forks
01FB001
01FB006
Inverness (AUT)
01FE002
01FB003
Port Hood
Indian Brook
Baddeck
01FJ003
Sydney A
01FJ002
River Denys
01FA001
Port Hastings Canal
Port Hastings
01FA003
01FJ001
Louisbourg
01FH001
01ER001
Eddy Point
Lower L'ardoise
Dickie Brook
Deming
INSET
Sable Island
SCALE 1:1,000,000 ÉCHELLE
30 40 50 60 70 80 90 100 110 Kilomètres
Kilomètre
1 Millimètre = 1 Kilomètre

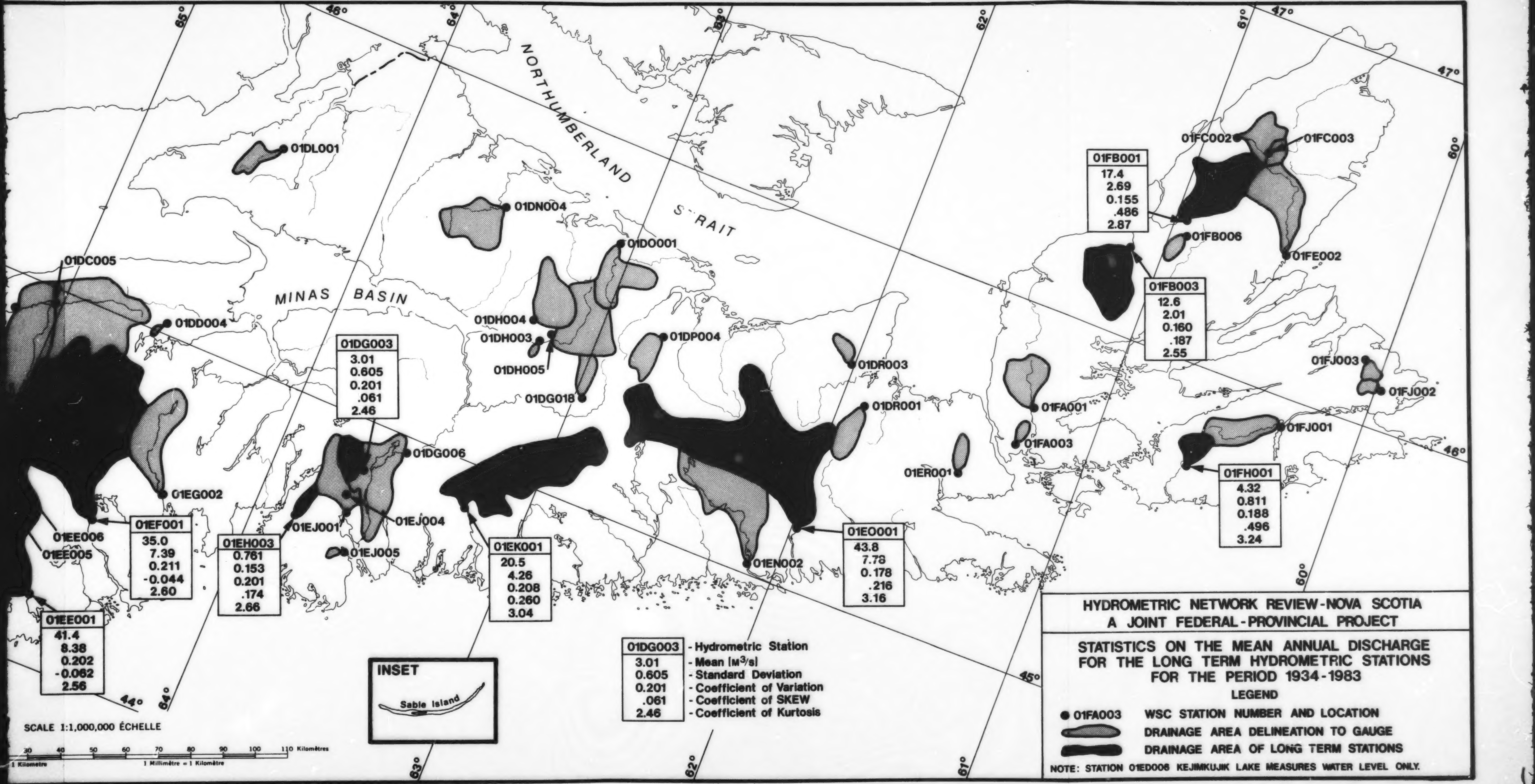
HYDROLOGIC NETWORK REVIEW - NOVA SCOTIA
A JOINT FEDERAL-PROVINCIAL PROJECT

ACTIVE [1983] HYDROMETRIC AND CLIMATOLOGICAL STATIONS

LEGEND

●01FA003	WSC HYDROMETRIC STATION NUMBER AND LOCATION
■Baddeck	AES CLIMATOLOGICAL STATION NAME AND LOCATION
▨	DRAINAGE AREA DELINEATION TO HYDROMETRIC GAUGE


BAY OF FUNDY
MINAS BASIN
NORTHUMBERLAND STRAIT
45°
44°
46°
67°
66°
65°
64°
63°
62°
61°
01DL001
01DN004
01DO001
01DC005
01DC007
01DD004
01DH004
01DH003
01DH005
01DP004
01DR003
01DR001
01DG018
01DG006
01ED007
1ED009
01DA001
01ED006
01ED005
01EE007
01EE004
01EE006
01EE005
01EG002
01EJ001
01EJ004
01EJ005
01EN002
01ER001
01FA003
01FA
01DG003
3.01
0.605
0.201
.061
2.46
01EA003
33.1
6.23
0 188
-0.050
2.53
01EC001
16.4
3.16
0.192
0.007
2.92
01EE001
41.4
8.38
0.202
-0.062
2.56
01EF001
35.0
7.39
0.211
-0.044
2.60
01EH003
0.761
0.153
0.201
.174
2.66
01EK001
20.5
4.26
0.208
0.260
3.04
01EO001
43.8
7.78
0.178
.216
3.16
INSET
Sable Island
01DG003 - Hydrometric Station
3.01 - Mean (M³/s)
0.605 - Standard Deviation
0.201 - Coefficient of Variation
.061 - Coefficient of SKEW
2.46 - Coefficient of Kurtosis
SCALE 1:1,000,000 ÉCHELLE
Kilometres 10 5 0 10 20 30 40 50 60 70 80 90 100 110 Kilomètres
1 Millimetre = 1 Kilometre
1 Millimètre = 1 Kilomètre


46°
65°
64°
63°
62°
61°
47°
60°
45°
44°
NORTHUMBERLAND STRAIT
MINAS BASIN
01DL001
01DN004
01DO001
01DC005
01DD004
01DH004
01DH003
01DH005
01DG018
01DP004
01DR003
01DR001
01DG006
01EG002
01EE006
01EE005
01EJ001
01EJ004
01EJ005
01EN002
01ER001
01FA001
01FA003
01FB006
01FC002
01FC003
01FE002
01FJ003
01FJ002
01FJ001
01DG003 3.01 0.605 0.201 .061 2.46
01EF001 35.0 7.39 0.211 -0.044 2.60
01EH003 0.761 0.153 0.201 .174 2.66
01EK001 20.5 4.26 0.208 0.260 3.04
01EO001 43.8 7.78 0.178 .216 3.16
01EE001 41.4 8.38 0.202 -0.062 2.56
01FB001 17.4 2.69 0.155 .486 2.87
01FB003 12.6 2.01 0.160 .187 2.55
01FH001 4.32 0.811 0.188 .496 3.24
INSET
Sable Island
SCALE 1:1,000,000 ÉCHELLE
30 40 50 60 70 80 90 100 110 Kilomètres
1 Kilometre
1 Millimètre = 1 Kilomètre

01DG003 - Hydrometric Station
3.01 - Mean [M³/s]
0.605 - Standard Deviation
0.201 - Coefficient of Variation
.061 - Coefficient of SKEW
2.46 - Coefficient of Kurtosis

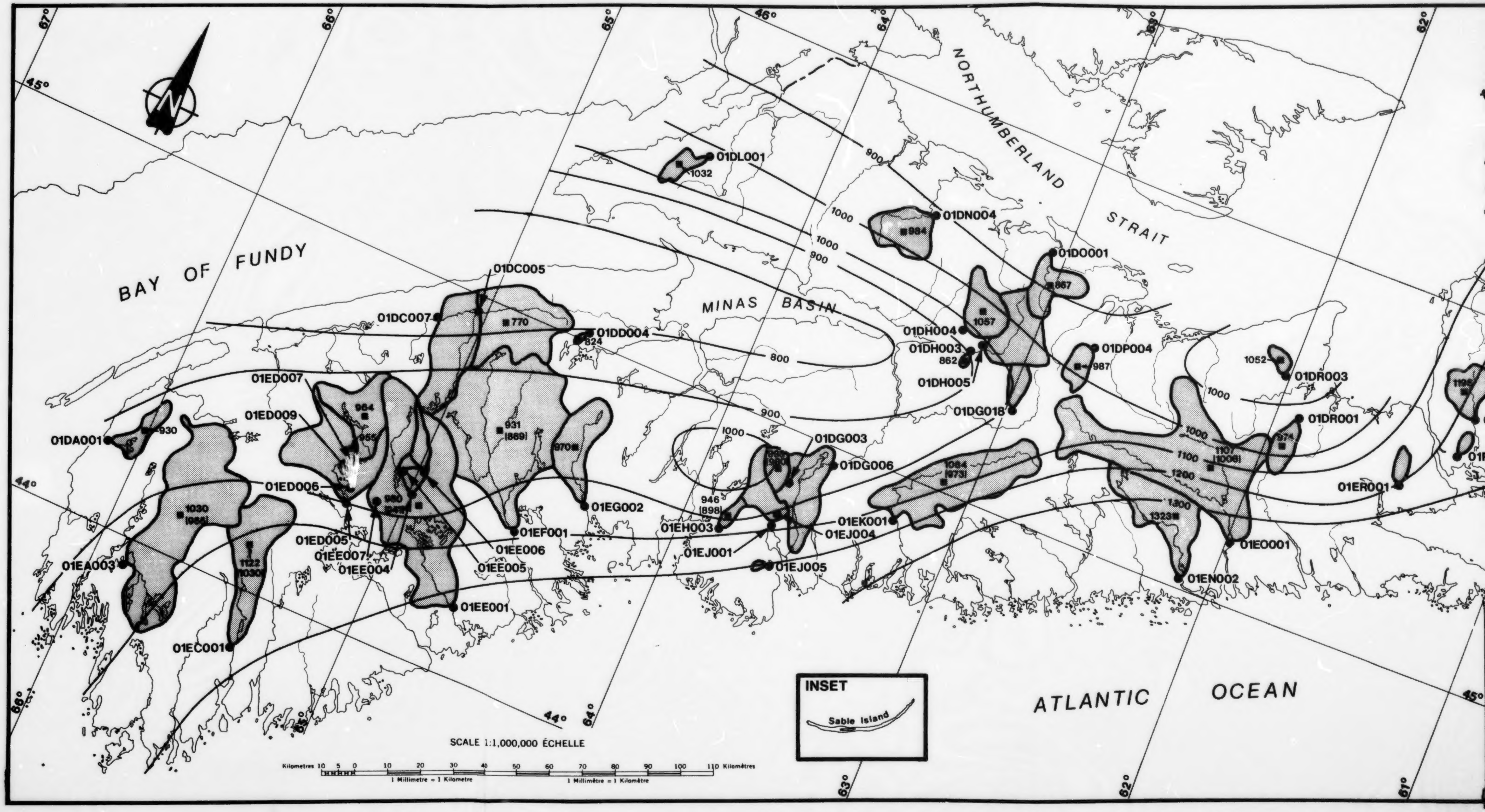
HYDROMETRIC NETWORK REVIEW-NOVA SCOTIA
A JOINT FEDERAL-PROVINCIAL PROJECT

STATISTICS ON THE MEAN ANNUAL DISCHARGE FOR THE LONG TERM HYDROMETRIC STATIONS FOR THE PERIOD 1934-1983

LEGEND

● 01FA003 WSC STATION NUMBER AND LOCATION
▨ DRAINAGE AREA DELINEATION TO GAUGE
■ DRAINAGE AREA OF LONG TERM STATIONS

NOTE: STATION 01ED006 KEJIMKUJIK LAKE MEASURES WATER LEVEL ONLY.


N
BAY OF FUNDY
MINAS BASIN
NORTHUMBERLAND STRAIT
ATLANTIC OCEAN
INSET
Sable Island
67°
66°
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64°
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45°
46°
44°
01DA001
930
01DC005
01DC007
770
01DD004
824
01DL001
1032
01DN004
984
01DO001
867
01DH004
1057
01DH003
862
01DH005
01DG018
01DP004
987
01DR003
1052
01DR001
974
01ER001
1196
01ED007
01ED009
964
955
01ED006
01ED005
01EE007
01EE004
960
01EE006
01EE005
01EE001
931
[869]
970
01EG002
01EF001
1030
[985]
01EA003
1122
[1030]
01EC001
01DG003
01DG006
1000
946
[898]
01EH003
01EJ001
01EJ004
01EJ005
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[973]
1107
[1009]
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01EO001
01EN002
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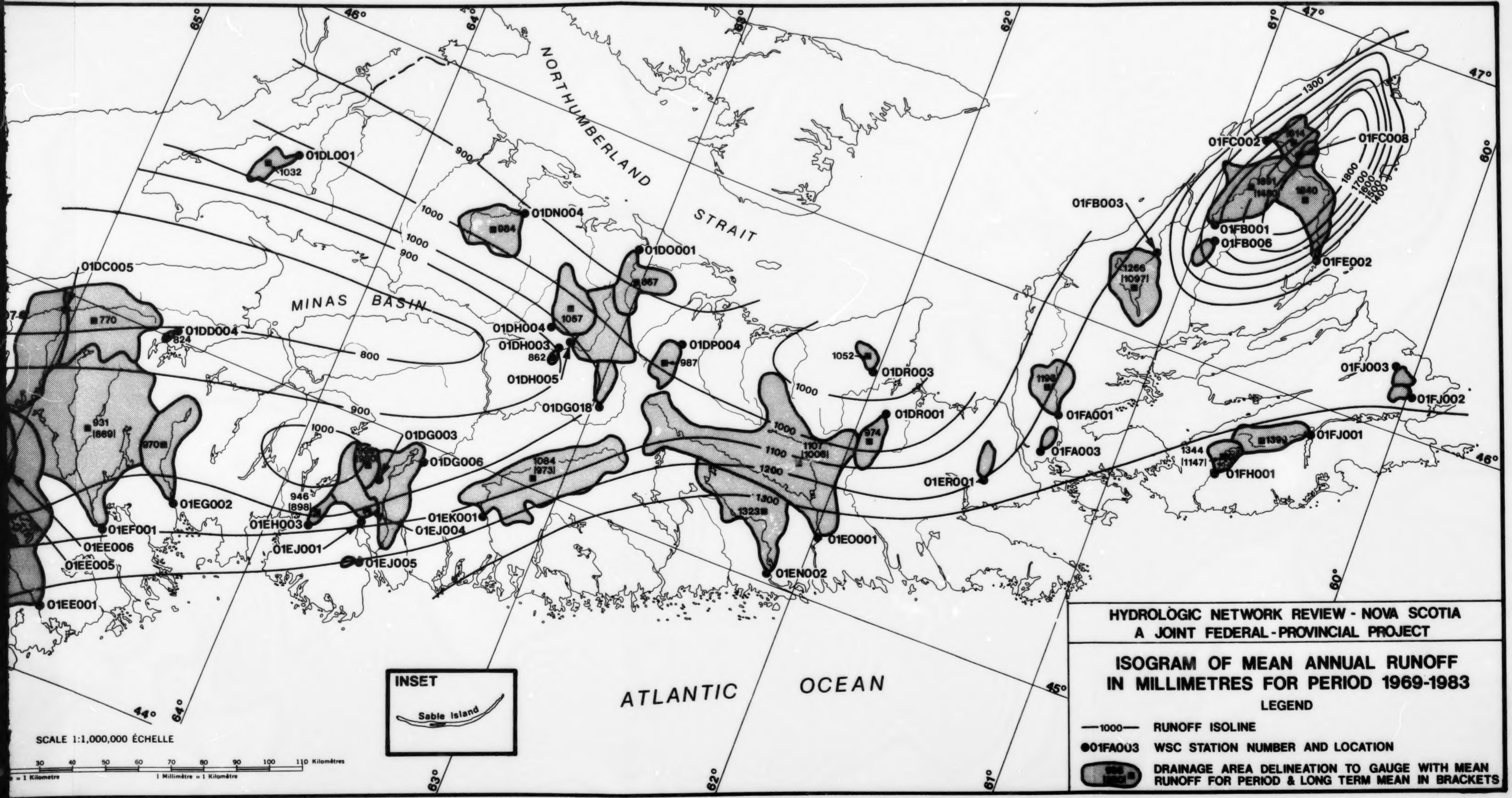
SCALE 1:1,000,000 ÉCHELLE
Kilometres 10 5 0 10 20 30 40 50 60 70 80 90 100 110 Kilomètres
1 Millimetre = 1 Kilometre
1 Millimètre = 1 Kilomètre


NORTHUMBERLAND
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MINAS BASIN
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Sable Island
SCALE 1:1,000,000 ÉCHELLE
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1 Millimètre = 1 Kilomètre
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1800

HYDROLOGIC NETWORK REVIEW - NOVA SCOTIA
A JOINT FEDERAL-PROVINCIAL PROJECT

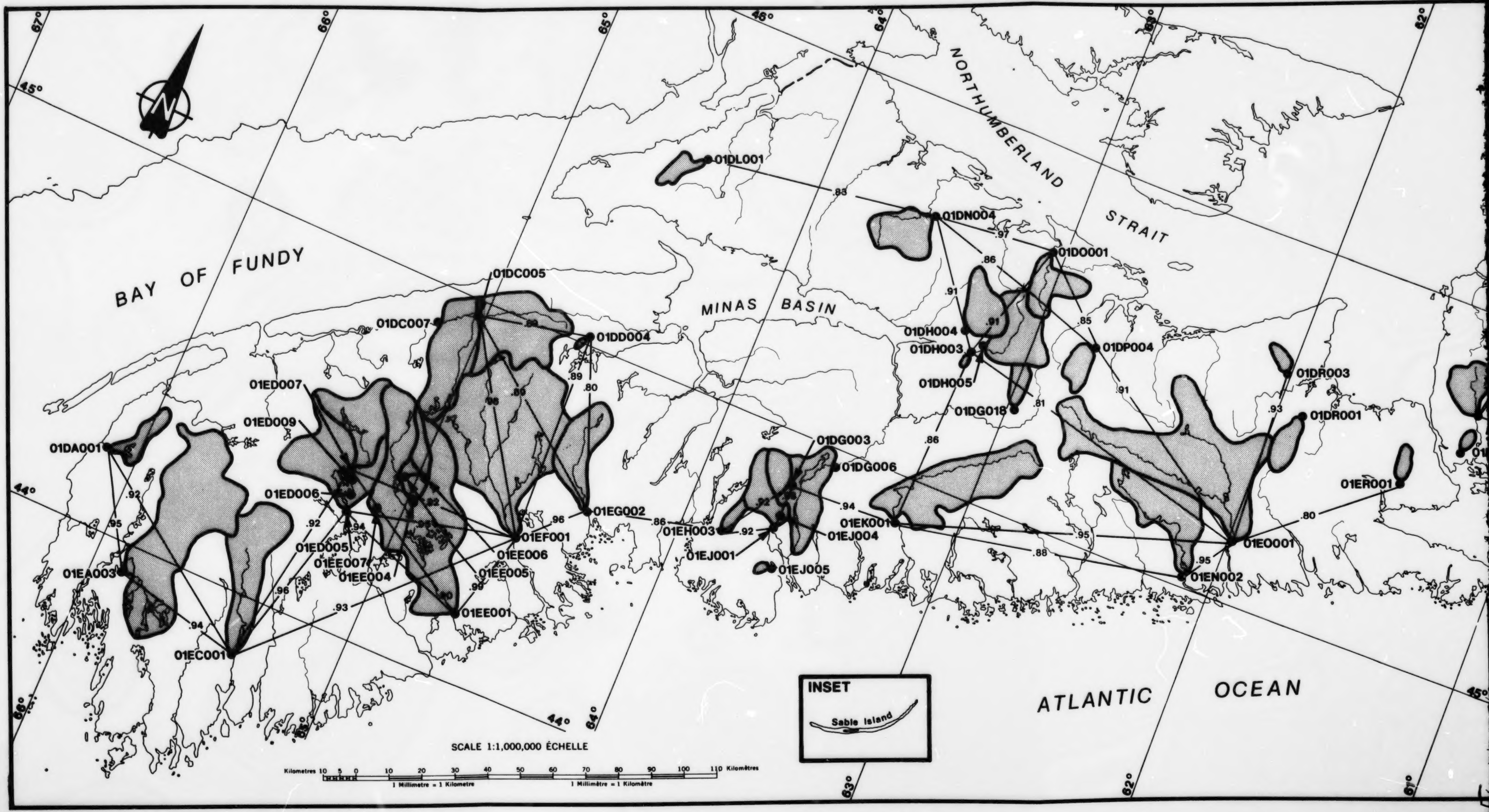
ISOGRAM OF MEAN ANNUAL RUNOFF IN MILLIMETRES FOR PERIOD 1969-1983

LEGEND

—1000— RUNOFF ISOLINE

●01FA003 WSC STATION NUMBER AND LOCATION

▨ DRAINAGE AREA DELINEATION TO GAUGE WITH MEAN RUNOFF FOR PERIOD & LONG TERM MEAN IN BRACKETS


N
BAY OF FUNDY
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NORTHUMBERLAND STRAIT
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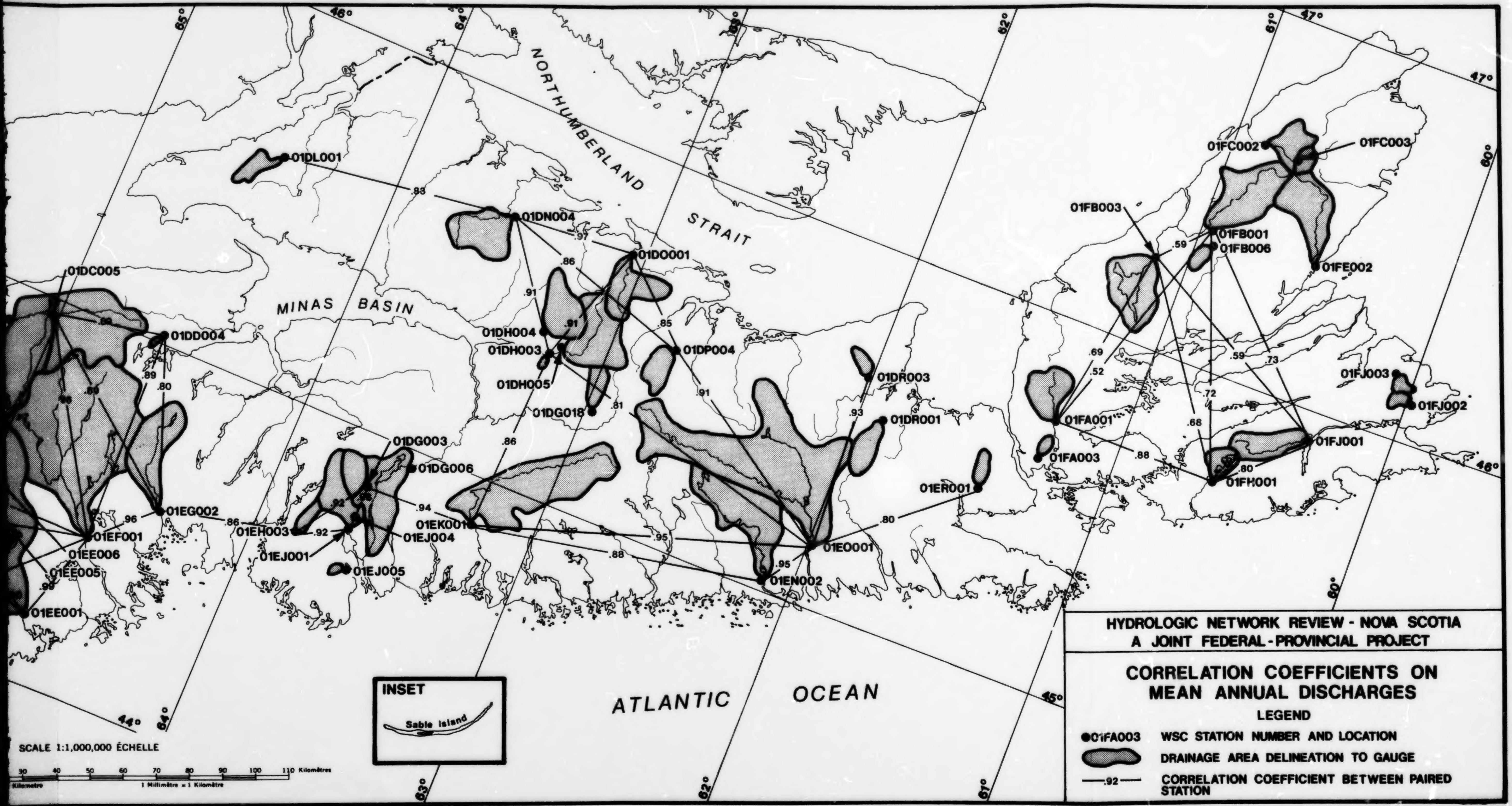
SCALE 1:1,000,000 ÉCHELLE
Kilometres 10 5 0 10 20 30 40 50 60 70 80 90 100 110 Kilomètres
1 Millimetre = 1 Kilometre
1 Millimètre = 1 Kilomètre


NORTHUMBERLAND STRAIT
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ATLANTIC OCEAN
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Sable Island
SCALE 1:1,000,000 ÉCHELLE
1 Millimètre = 1 Kilomètre
110 Kilomètres
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HYDROLOGIC NETWORK REVIEW - NOVA SCOTIA
A JOINT FEDERAL-PROVINCIAL PROJECT

CORRELATION COEFFICIENTS ON MEAN ANNUAL DISCHARGES

LEGEND

- ●01FA003 WSC STATION NUMBER AND LOCATION
- ▨ DRAINAGE AREA DELINEATION TO GAUGE
- —.92— CORRELATION COEFFICIENT BETWEEN PAIRED STATION